Salix candida Flueggé ex Wild. (sageleaf willow)
A Technical Conservation Assessment

Prepared for the USDA Forest Service,
Rocky Mountain Region,
Species Conservation Project

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Karin Decker
Colorado Natural Heritage Program
Colorado State University
Fort Collins, CO

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AUTHOR'S BIOGRAPHY

Karin Decker is an ecologist with the Colorado Natural Heritage Program (CNHP). She works with CNHP's Ecology and Botany teams, providing ecological, statistical, GIS, and computing expertise for a variety of projects. She has worked with CNHP since 2000. Prior to this, she was an ecologist with the Colorado Natural Areas Program in Denver for four years. She is a Colorado native who has been working in the field of ecology since 1990, including four summers at the Rocky Mountain Biological Laboratory in Gothic, Colorado. Before returning to school to become an ecologist she graduated from the University of Northern Colorado with a B.A. in Music (1982). She received an M.S. in Ecology from the University of Nebraska (1997), where her thesis research investigated sex ratios and sex allocation in a dioecious annual plant.

COVER PHOTO CREDIT

Salix candida (sageleaf willow). Photograph by Brian Elliott. Used with permission.

SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF *SALIX CANDIDA*

Status

Salix candida (sageleaf willow) is a boreal species whose distribution is concentrated in the northern tier of The United States, including Alaska, and in Canada from Newfoundland to British Columbia. Within USDA Forest Service Region 2, it is known from 32 disjunct occurrences (15 in Colorado, 10 in Wyoming, and seven in South Dakota). Five additional locations in Wyoming are outside Region 2. Of the 32 occurrences within Region 2, 16 are on National Forest System lands: five on the Arapaho-Roosevelt and Pike-San Isabel national forests in Colorado, 10 on the Medicine Bow and Shoshone national forests in Wyoming, and one on the Black Hills National Forest in South Dakota. *Salix candida* is currently considered a sensitive species in Region 2, but it is not listed as threatened or endangered under the federal Endangered Species Act. The NatureServe global conservation status rank for *S. candida* is G5; state Natural Heritage Program rankings are S1 in South Dakota, and S2 in Colorado and Wyoming.

Primary Threats

The primary and immediate threat to the persistence of *Salix candida* in Region 2 is hydrologic alteration. The pervasive nature of this threat could drastically reduce or eliminate suitable habitat for *S. candida* in Region 2. Global climate change or consequences arising from small population sizes could also eliminate *S. candida* from Region 2 over longer periods. Less immediate threats include grazing, road construction and maintenance, peat mining, recreational use, alteration of natural fire regime, and invasive species. These threats are more likely to decrease the vigor and number of occurrences rather than eliminate the species from Region 2.

Primary Conservation Elements, Management Implications and Considerations

Occurrences of *Salix candida* in Region 2 are generally small and isolated from each other, in habitat patches that are relatively rare on the landscape. Abundance and trend data from known occurrences are a priority for *S. candida* because this information will clarify the relative importance of these occurrences to the conservation of the species in Region 2. The identification of potential habitat and the search for additional occurrences, especially on National Forest System lands, is also a high priority for *S. candida*.

Occurrences of *Salix candida* in Region 2 are most vulnerable to changes in the environment that affect its peatland habitat. Hydrological modifications are pervasive throughout the range of this species, and natural environmental changes may also affect its habitat. In addition, changes in precipitation patterns and effects of natural disturbances elsewhere in the watershed may lead to altered hydrology that is detrimental to the persistence of *S. candida*. In these instances, management policy could focus on mitigating these effects when feasible. Any management activities that maintain the natural hydrologic regime of this habitat will tend to contribute to the persistence of *S. candida*. Examples of these activities include the regulation and monitoring of hydrological modifications, domestic grazing, fire suppression or reclamation, logging, mining, and road construction.

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INTRODUCTION

This assessment is one of many being produced to support the Species Conservation Project for the Rocky Mountain Region (Region 2), USDA Forest Service (USFS). *Salix candida* is the focus of an assessment because it is a disjunct species with an extremely limited distribution within the region and because Region 2 has listed it as a sensitive species (USDA Forest Service, Rocky Mountain Region 2005). Within the National Forest System, a sensitive species is a plant or animal whose population viability is identified as a concern by a Regional Forester because of significant current or predicted downward trends in abundance or significant current or predicted downward trends in habitat capability that would reduce its distribution (USDA Forest Service, Rocky Mountain Region 2003). A sensitive species may require special management, so knowledge of its biology and ecology is critical. This assessment addresses the biology of *S. candida* throughout its range in Region 2. This introduction defines the goal of the assessment, outlines its scope, and describes the process used in its production.

Goal of Assessment

Species assessments produced as part of the Species Conservation Project are designed to provide forest managers, research biologists, and the public with a thorough discussion of the biology, ecology, conservation status, and management of certain species based on available scientific knowledge. Assessment goals limit the scope of the work to critical summaries of scientific knowledge, discussion of broad implications of that knowledge, and outlines of information needs. The assessment does not seek to develop specific management recommendations. Instead, it provides the ecological background upon which management must be based and focuses on the consequences of changes in the environment that result from management (i.e., management implications). Furthermore, this assessment cites management recommendations proposed elsewhere and examines the success of those recommendations that have been implemented.

Scope of Assessment

The assessment examines the biology, ecology, conservation status, and management of *Salix candida* with specific reference to the geographic and ecological characteristics of the USFS Rocky Mountain Region. Although much of the literature on this species and its congeners is derived from field investigations outside the region, this document places that literature in the ecological context of the central and southern Rocky Mountains and adjacent Great Plains. Similarly, this assessment is concerned with reproductive behavior, population dynamics, and other characteristics of *S. candida* in the context of the current environment rather than under historical conditions. Previous work by Glisson (2003) treated these topics in detail for the *S. candida* occurrence on National Forest System lands in the Black Hills of South Dakota. This assessment incorporates information from that document.

In producing the assessment, I examined specimens of *Salix candida* at University of Colorado Herbarium (COLO), Colorado State University (CSU), and Rocky Mountain Herbarium (RH), and obtained element occurrence records from the Colorado Natural Heritage Program, the Wyoming Natural Diversity Database, and the South Dakota Natural Heritage Program. I also reviewed peer-reviewed literature, non-refereed publications, research reports, and data accumulated by resource management agencies and other investigators. Although this species is mentioned in a variety of sources, there are no publications devoted exclusively to *S. candida* other than the original published description of localized hybridization (Rowlee and Wiegand 1896) and the assessment of Glisson (2003). Because basic research has not been conducted on many facets of the biology of *S. candida*, literature on its congeners was used to make inferences. The peer-reviewed and non-refereed literature on the genus *Salix* and its included species is more extensive and includes other disjunct or rare species. Because refereed literature is the accepted standard in science, this assessment emphasizes peer-reviewed publications, especially in addressing general ecological and management concepts. Non-refereed publications or reports were regarded with greater skepticism, but they were used in the assessment since they are often the only source of information about occurrences of *S. candida* in Region 2.

Treatment of Uncertainty in Assessment

Science is a rigorous, systematic approach to obtaining knowledge in which competing ideas regarding how the world works are measured against observations. Because our descriptions of the world are always incomplete and our observations are limited, science focuses on approaches for dealing with uncertainty. A commonly accepted approach to science is based on a progression of critical experiments to develop strong inference (Platt 1964). It is difficult, however, to conduct experiments that produce clean results in the ecological sciences. Often, observations, inference, critical thinking, and models must be relied on to guide our understanding of ecological relations. I used information on the biology and ecology of other *Salix* species to make inferences regarding similar characteristics for *S. candida*, but these inferences have not been tested.

Treatment of This Document as a Web Publication

To facilitate the use of species assessments in the Species Conservation Project, they will be published on the Region 2 World Wide Web site (http://www.fs.fed.us/r2/projects/scp/assessments/index.shtml). Placing documents on the Web makes them available to agency biologists and the public more rapidly than publishing them as reports. More importantly, it facilitates revision of the assessments, which will be accomplished based on guidelines established by Region 2.

Peer Review of This Document

Assessments developed for the Species Conservation Project have been peer reviewed prior to release on the Web. This assessment was reviewed through a process administered by the Society for Conservation Biology, employing two recognized botanic experts. Peer review was designed to improve the quality of communication and to increase the rigor of the assessment.

MANAGEMENT STATUS AND NATURAL HISTORY

Management Status

Salix candida is known from 32 locations within Region 2 (**Figure 1**, **Table 1**); 15 occurrences are known from Colorado, 10 from Wyoming, and 7 from South Dakota. Of these 32 occurrences, 16 are located on National Forest System lands. There is one occurrence on the Black Hills National Forest in South Dakota. In Wyoming, three occurrences are on the Shoshone National Forest, and seven are located on the Medicine Bow National Forest. One of these seven (occurrence 23 in **Table 1**) is considered historic and has not been relocated since the original specimen was collected. In Colorado, one occurrence is on the Arapaho-Roosevelt National Forest, and four are at least in part on the Pike-San Isabel National Forest.

Spackman et al. (1997) indicated that *Salix candida* is also known from Hinsdale and LaPlata counties, on the Gunnison and San Juan national forests. These records are based on plot data from William L. Baker's survey work from 1985. No specimens were collected to document these occurrences, and ecologists with the Colorado Natural Heritage Program (CNHP) have been unable to relocate the occurrences. Observations by CNHP staff suggest that these records are likely to be misidentifications of *S. brachycarpa* or similar species, since the habitats are atypical for *S. candida*. These locations are shown as open circles in **Figure 1**, but they are not discussed in this document.

There are five additional occurrences of *Salix candida* in Wyoming that fall outside the administrative boundaries of Region 2. One is located on the Bridger-Teton National Forest (Region 4), two are in Yellowstone National Park, one is on the National Elk Refuge managed by the U.S. Fish and Wildlife Service (USFWS), and the fifth is an historic record from private lands.

The current NatureServe global conservation status rank for *Salix candida* is G5. The global (G) rank is based on the status of a taxon throughout its range. A G5 ranking is defined as "Secure - Common; widespread and abundant" (NatureServe 2006). State Natural Heritage Program rankings are S1 for South Dakota, and S2 for Colorado and Wyoming (NatureServe 2006). The state (S) rank is based on the status of a taxon in an individual state. The S1 rank signifies that the species is "critically imperiled in the state because of extreme rarity (often 5 or fewer occurrences) or because of some factor(s) such as very steep declines making it especially vulnerable to extirpation from the state." A rank of S2 indicates that the species is "imperiled in the state/province because of rarity due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors making it very vulnerable to extirpation from the nation or state/province" (NatureServe 2006).

Region 2 of the USFS currently lists *Salix candida* as a sensitive species (USDA Forest Service, Rocky Mountain Region 2005). The species is also listed on the Colorado Bureau of Land Management (BLM) State Director's Sensitive Species List for the Royal Gorge Field Office (USDI Bureau of Land Management 2000).

Management status for *Salix candida* locations varies within Region 2. The occurrence on the Black Hills National Forest in South Dakota (occurrence 20 in **Table 1**) is located in the McIntosh Fen, which is part of a Botanical Special Interest Area (SIA) designated in 1997. The USFS must manage the SIA in such a way

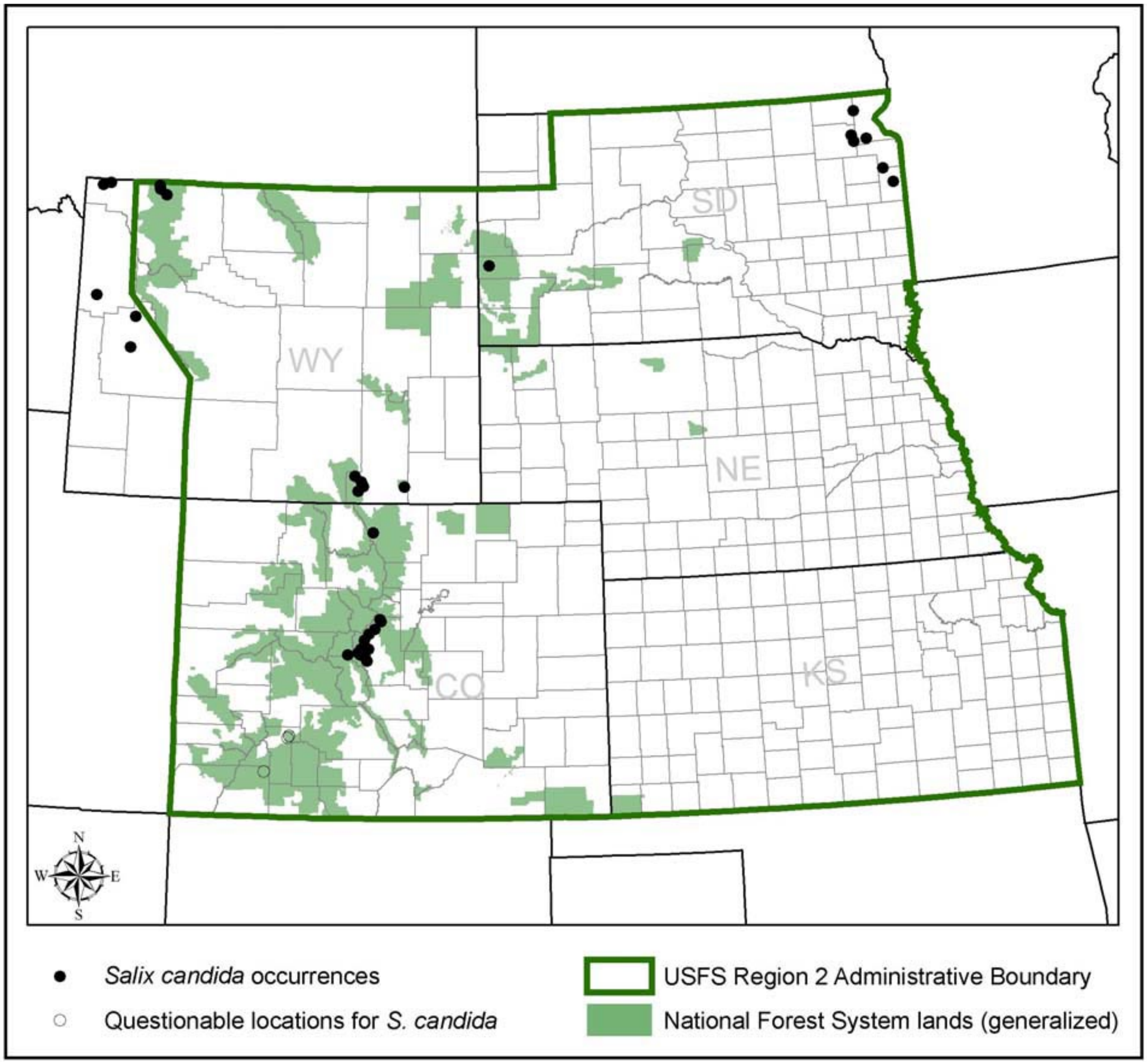


Figure 1. Distribution of *Salix candida* in USDA Forest Service Region 2.

that the fen and the associated botanical features for which it was established are not impaired (Hornbeck et al. 2003). Another South Dakota occurrence (occurrence 17 in **Table 1**) is located at the Waubay National Wildlife Refuge. Although planning in this area clearly emphasizes migratory waterfowl habitat, management goals are to preserve, restore, and enhance the ecological diversity of grasslands, wetlands, and native woodlands of the Refuge (U.S. Fish and Wildlife Service 2002). The remaining five South Dakota occurrences are on privately owned lands, and management conditions are unknown.

In Wyoming, the Swamp Lake occurrence (occurrence 30 in **Table 1**) is within an SIA on the Shoshone National Forest. Two other Wyoming locations are within the Sheep Mountain National Game Refuge on the Medicine Bow National Forest (occurrences 25 and 26 in **Table 1**), and one historic location (occurrence 23 in **Table 1**) is within designated deer and elk winter range. These last three areas have some use restrictions that could protect *Salix candida* occurrences. The other seven Wyoming locations of Region 2 are on USFS lands with management prescriptions emphasizing recreation or renewable resources.

Colorado occurrences on federally managed land include one within the Boston Peak Fen Research Natural Area (RNA) on the Arapaho-Roosevelt National Forest (occurrence 2 in **Table 1**) and four on lands of the Pike-San Isabel National Forest (occurrences 1, 5, 6, and 12 in **Table 1**) that have management prescriptions for either roaded-natural recreation opportunities or big

Table 1. Documented occurrences of *Salix candida* in USDA Forest Service Region 2. Occurrences are arranged by location (state and county) and arbitrarily numbered. Historic occurrences are shown with shading.

	State County	Land ownership/ Management	Date of last observation	Location	Elevation (ft.)	Habitat[1]	Estimated population size[2]	Source ID[3]
COLORADO								
1	CO Lake	USDA Forest Service (USFS) Pike-San Isabel National Forest	25-Aug-2004	Southern Lake County	~9,000	Flat fen, saturated soil	20-100	*B. Elliott #13227*
2	CO Larimer	USFS Arapaho-Roosevelt National Forest Boston Peak Fen Research Natural Area	12-Aug-1996	Boston Peak Fen (north of Chambers Lake)	8,900	Small fen, wet soil, moss covered hummocks	500	CNHP-06 *W.A. Weber #16343, w/ A. Bujakiewic* *G.W. Argus #12607*
3	CO Park	The Nature Conservancy	03-Aug-2000	High Creek Fen	9,200	Extremely rich fen fed by calcareous seeps; on hummocks near flowing water in wettest areas	5000+	CNHP-05 *D.J. Cooper #1676,* *W.A. Weber #18022 w/ D. Cooper* *J. Sanderson #939*
4	CO Park	Private / State of Colorado / Denver Water Board	04-Aug-1995	Old Railroad – Antero Reservoir NW	8,990	Calcareous peatlands, on hummocks in wetter areas	100-1000	CNHP-08 and CNHP-11 *D.J. Cooper #1756* *C. William and T. Penland #3756*
5	CO Park	USFS Pike-San Isabel National Forest	09-Sep-1995	Duck Creek	9,800	Rich fen, peaty soils near creek	80	CNHP-10
6	CO Park	USFS Pike-San Isabel National Forest	12-Sep-2000	Geneva Park	9,600	Rich fen	50	CNHP-15 *N. Lederer #GP-95-57 w/ P. Murphy* *W.A. Weber #18079 w/ T. Hogan* (incorrectly in Clear Creek County)
7	CO Park	Private	15-Jul-2000	Wahl/Coleman Ranch	9,700	On hummocks in extreme rich fen	unknown	CNHP-12
8	CO Park	Private	26-Aug-1995	Hollthusen Gulch/ Tarryall Creek Fen	9,960	Rich fen-Extreme rich fen complex	100-1000+	CNHP-13
9	CO Park	Private	13-Sep-2000	South Fork South Platte Fen	9,150	Extreme rich fen	1000	CNHP-14 *S. Spackman #SS-00-45.C* *J. Sanderson #S952-957*
10	CO Park	Private	24-Aug-1995	High Creek at Warm Spring	9,900	Extreme rich fen, riparian peatland	unknown	CNHP-16
11	CO Park	Private	05-Aug-1990	Trout Creek	9,220	Hummocky, extremely rich fen	unknown	CNHP-09 and CNHP-17 *D.J. Cooper #1909*
12	CO Park	Private / USFS Pike-San Isabel National Forest	13-Sep-2000	Crooked Creek Spring	10,040	Extreme rich fen	50	CNHP-18

Table 1 (cont.).

	State County	Land ownership/ Management	Date of last observation	Location	Elevation (ft.)	Habitat[1]	Estimated population size[2]	Source ID[3]
13	CO Park	Private	09-Sep-2000	Sheep Creek	9,440	Extreme rich fen - saturated soils	100	CNHP-19 *S. Spackman #SS-00-39.A w/ D. Culver & J. Rocchio*
14	CO Park	Private	01-Sep-1999	High Creek north of Black Mtn.	9,500	Extreme rich fen	75-100	CNHP-20
15	CO Park	Private	23-Aug-1997	Twelve Mile Creek	9,900	Wet fen meadow	unknown	*T. Kelso #97-171 w/ G. Maentz, W.A. Weber, & R. Wittmann.*
SOUTH DAKOTA								
16	SD Day	Private	04-Jun-1986	Althoff Fen	unknown	Narrow, gently sloping fen zone at base of gravelly bluffs along creek; saturated organic substrate	<10	SDNHP-05 *D.J. Ode # 85-7 SD*
17	SD Day	U.S. Fish and Wildlife Service	1983	Waubay National Wildlife Refuge	unknown	Seepage area	2	SDNHP-04
18	SD Deuel	Private	12-Jun-1984	Jacob Springs	unknown	Seepage area on north-facing slope	patch 10 m in diameter	SDNHP-03
19	SD Grant	Private	1986	Yellow Bank Fens	unknown	Fen	unknown	SDNHP-02
20	SD Pennington	USFS Black Hills National Forest	2001	McIntosh Fen (Castle Creek Fen)	6,410	Fen; wet, springy, organic soil	several hundred	SDNHP-01
21	SD Roberts	Private	18-Oct-1995	County Road 34	unknown	Rich fen	infrequent	SDNHP-06
22	SD Roberts	Private	15-Aug-2002	Kriz Fens	unknown	Calcareous fen	1	SDNHP-07 *D.J. Ode #02-51 SS.*
WYOMING								
23	WY Albany	USFS Medicine-Bow National Forest	24-Jun-1930	Centennial Valley bogs	8,700	Boggy, springy draws	unknown	WYNDD-01 *A. Nelson #1755, #8684* *L. Kelso #806*
24	WY Albany	USFS Medicine-Bow National Forest	11-Aug-2002	Crow Creek Fen	7,920	On scattered mounds surrounded by flooded muck; soils histic and water saturated	occasional	WYNDD-02 *R.D. Dorn #4385, #5167* *W. Fertig #18620*
25	WY Albany	USFS Medicine-Bow National Forest Sheep Mtn. National Game Refuge	20-Aug-2004	Sheep Mountain Fen	9,220	Headwaters of large, open rich fen; concentrated in narrow bands on opposite sides and scattered above on hummocky moss cover	50-100	WYNDD-07 *M. Jankovsky-Jones #sn* *B. Heidel #sn*

Table 1 (cont.).

	State County	Land ownership/ Management	Date of last observation	Location	Elevation (ft.)	Habitat[1]	Estimated population size[2]	Source ID[3]
26	WY Albany	USFS Medicine-Bow National Forest Sheep Mtn. National Game Refuge	30-Aug-2004	Hecht Creek fen	9,160	Rich fen in an elongated headwaters basin with a range of slopes and vegetation structure	2	WYNDD-14 *B. Heidel #sn*
27	WY Albany	USFS Medicine-Bow National Forest	15-Sep-1998	Sand Lake Road - north	9,100	Scattered low hummocks in *Carex simulata* fen	unknown	WYNDD-11 *W. Fertig #18615*
28	WY Albany	USFS Medicine-Bow National Forest	09-Aug-2002	Sand Lake Road - south	8,950	Fen in a shallow basin with open shrub carr	20-100	WYNDD-12 *B. Heidel, J. Proctor & S. Laursen. #sn*
29	WY Albany	USFS Medicine-Bow National Forest	27-Sep-2003	Strain Creek - Lake Owen?	8,830	Discrete peatland habitat of low stature, sparse shrub cover within a broad wetland opening of predominantly wetland thicket upper stream reach	locally common	WYNDD-13
30	WY Park	USFS Shoshone National Forest	31-Jul-1999	Swamp Lake	6,600	Found in floating mats of *Carex simulata*, marly hummocks of *Eleocharis* and *Triglochin*, *C. rostrata* marsh, *Picea glauca* swamp forest and muskeg, and *Alnus* woodlands	abundant	WYNDD-04 *R.D. Dorn #4121, #4123* *W. Fertig #13349* *B.E. Nelson, #16883*
31	WY Park	USFS Shoshone National Forest	07-Aug-1995	West of Lily Lake	7,720	Occurring on granitic parent material in willow meadow surrounding floating mat	250-350	WYNDD-09 *S. Mills #148, #149, #165*
32	WY Park	USFS Shoshone National Forest	22-Jul-2005	Clarks Fork	6,970	Elongate fen with vegetation complex	<20	WYNDD-15
WYOMING, outside REGION 2								
33	WY Park	National Park Service Yellowstone National Park	13-Aug-1985	Swan Lake flats	7,200	Histosol soil and glacial till	sparse	WYNDD-05 *J. Pierce, S. Cooper and S. Chadde #1409* *J. Pierce and S. Cooper #1256*
34	WY Park	National Park Service Yellowstone National Park	02-Jul-1997	Blacktail Pond	6,600	Floating vegetation at edge of lake	100+	WYNDD-06
35	WY Sublette	Private	01-Jul-1961	Green River near Daniel Junction	7,200	On ground along irrigation ditch	unknown	WYNDD-03 *G.W. Argus #16-61*
36	WY Sublette	USFS Bridger-Teton National Forest	01-Aug-1998	Cold water spring due north of Kendall Warm Springs	7,800	Quaking mats and hummocks on marly, saturated soils	uncommon	WYNDD-08 *W. Fertig #15059*

Table 1 (concluded).

	State County	Land ownership/ Management	Date of last observation	Location	Elevation (ft.)	Habitat[1]	Estimated population size[2]	Source ID[3]
37	WY Teton	U.S. Fish and Wildlife Service National Elk Refuge	06-Aug-1997	Flat Creek Fen	6,200	Occurs primarily on slightly elevated and drier hummocks or ant mounds within moist, calcareous wetland meadows bordering small streams, ponds, and ditchbanks	5000-10000	WYNDD-10 *W. Fertig #17793, #17843, #17853, #17885, #17917, #17940*

[1]Habitat type names are given as in the original source

[2]Population sizes are numbers of individual plants, or qualitative descriptions of abundance.

[3]Sources include element occurrence data from Colorado Natural Heritage Program (CNHP), South Dakota Natural Heritage Program (SDNHP), and Wyoming Natural Diversity Database (WYNDD), and herbarium labels; Element Occurrence ID's are of the format CNHP-00 and herbarium label ID's are collector name and collection number

game winter range. One Colorado location (occurrence 4 in **Table 1**) is at least in part on lands owned by the Denver Water Board, and possibly the Colorado State Land Board and the Colorado Division of Wildlife. One Colorado occurrence (occurrence 3 in **Table 1**) is on an ecological preserve that The Nature Conservancy owns and manages. The remaining eight Colorado locations are on privately owned lands, where management is unknown but has historically emphasized agricultural or extractive uses. Lands under private ownership have no protective or special management designation.

Salix candida is represented in 11 Potential Conservation Areas (PCAs), designated by the CNHP as having natural heritage significance. PCA boundaries do not confer any regulatory protection to the site, nor do they automatically exclude all activity. PCA boundaries are based primarily on factors relating to ecological systems, and they represent the best professional estimate of the primary area supporting the long-term survival of the targeted species or plant associations. Such boundaries delineate ecologically sensitive areas where careful planning and management of land-use practices are advisable to ensure that they are compatible with protection of natural heritage resources and sensitive species (Colorado Natural Heritage Program Site Committee 2002).

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

Salix candida has never been a candidate for threatened or endangered status under the Endangered Species Act. *Salix arizonica* was at one time proposed for Endangered status (Center for Plant Conservation 2004), but currently no *Salix* species are federally listed. At the edges of its range in North America, several states give *S. candida* special status by statute. In Washington, it is designated sensitive; in Pennsylvania, it is endangered; and in Maine and Ohio, it is threatened. No state within Region 2 has given *S. candida* special status.

Because *Salix candida* is a sensitive species in Region 2, USFS personnel are required to "develop and implement management practices to ensure that species do not become threatened or endangered because of Forest service activities" (USDA Forest Service Manual, Region 2 supplement, 2670.22). These management practices may include developing an individual species conservation strategy. As of this writing, however, a conservation strategy has not been written for this species at a national or regional level by the USFS or any other federal agency.

Two regional federal policy documents provide specific management direction for peatland habitats where *Salix candida* occurs. The USFWS Regional Policy on the Protection of Fens (U.S. Fish and Wildlife Service 1998) made the protection of fens a priority in the USFWS Mountain-Prairie Region. This memo designates functioning fens as Resource Category 1 (considered "unique and irreplaceable on a national basis or in the ecoregion section"), with a mitigation goal of "no loss of existing habitat value." The USFWS Regional Policy on the Protection of Fens decreases the likelihood that the U.S. Army Corps of Engineers will permit peat mining under Section 404 of the Clean Water Act, but it does not prohibit application for such permits (Carey personal communication 2006). USFS Rocky Mountain Region Memo 2070/2520-72620, entitled Wetland Protection - Fens and signed by the Director of Renewable Resources, also gives regional guidance on fens. This memo informs forest supervisors of the USFWS policy and urges USFS personnel to "give careful consideration to avoiding impacts or identifying opportunities for restoration of these rare and irreplaceable habitats where they occur on National Forest System lands."

Salix candida is an obligate wetland indicator species across its entire range in the United States (USDA Natural Resources Conservation Service 2005), and a variety of federal regulations and policies require special consideration for wetlands where it occurs. The primary federal law regulating wetland habitats is Section 404 of the Federal Water Pollution Control Act (Clean Water Act) of 1977 (33 U.S.C. ss/1251 et seq.). Activities in wetlands regulated under this Act are required to avoid wetland impacts where practicable, to minimize potential impacts to wetlands, and to compensate unavoidable impacts through restoration or mitigation. The 2001 Supreme Court decision in Solid Waste Agency of Northern Cook County (SWANCC) vs. U.S. Army Corps of Engineers determined that Section 404 does not extend regulatory coverage to wetlands not adjacent to navigable waters ("isolated wetlands"). The provisions of the Clean Water Act would no longer regulate wetlands lacking connections to surface water, such as streams. As of this writing, Region 2 sites that support *S. candida* are not generally considered isolated wetlands and continue to be regulated under Section 404.

Federal codes and regulations pertaining to federal actions or to those on USFS lands include the National Environmental Policy Act (NEPA) of 1969 (42 U.S.C. 4321-4347), the Organic Administration Act of 1897 (16 U.S.C. 475), the Multiple Use – Sustained Yield Act of 1960 (16 U.S.C. 528), the National Forest Management Act of 1976 (16 U.S.C. 1600-1602, 1604, 1606, 1608-1614), the Federal Land Policy and Management Act of 1976 (43 U.S.C. 1701-1782, FSM 2729), the Forest Service Manual, and individual Forest Management Plans. The Forest Service Watershed Conservation Practices Handbook (FSH 2909.25) provides guidance on the protection of soil, aquatic, and riparian systems. These codes and regulations all provide some degree of focus on the preservation of water resources, including wetlands. Finally, a policy of "no-net-loss" of wetlands has been a national goal since first announced as an administration policy under President George H.W. Bush in 1989.

Adequacy of current laws and regulations

The above-mentioned laws and regulations can be powerful tools for the conservation of *Salix candida*, but fens in Region 2 need additional protection. Regulations defined by the U.S. Department of Interior and the U.S. Department of Agriculture still consider peat a renewable resource (USDI Bureau of Mines 1994) and saleable mineral (FSM 2822.1). For occurrences that might be found on privately owned lands, current laws and regulations are inadequate to prevent damage or destruction of the habitat. As of this writing, there were three active peat mining permits in Colorado, including one in South Park (Colorado Division of Minerals and Geology 2006). Future permitting of peat mining under Section 404 is unlikely due to the USFWS Regional Policy on the Protection of Fens (Carey personal communication 2006), but the possibility has not been completely eliminated.

Adequacy of current enforcement of laws and regulations

Current knowledge of *Salix candida* trends is insufficient to determine the adequacy of current enforcement of laws and regulations for most locations. There are no confirmed cases in which an occurrence of *S. candida* in Region 2 was extirpated due to human activities or by the failure to enforce any existing regulations. This does not necessarily indicate that current regulations or their enforcement are adequate for its protection or its habitat. A number of *S. candida* at locations on non-USFS lands in Region 2 have not been observed for many decades; it is impossible to determine if extirpations or impacts from human activities have taken place. It is also possible that the small size of some occurrences is the result of human activities. For instance, South Dakota National Heritage Program records speculate that at one location on private land, herbicide spraying may have reduced the occurrence to two plants (South Dakota Natural Heritage Program 2004). Possible isolated incidents of extirpation do not threaten the persistence of *S. candida* in Region 2, but a steady, gradual loss of individual occurrences over time could easily contribute to a contraction of the species' range. Loss of Region 2 populations could reduce the genetic diversity of the species as a whole, as well as depress its resilience in the face of genetic, demographic, and environmental stochasticities (Huenneke 1991, Millar and Libby 1991).

In Region 2, where *Salix candida* is found only in small patches of isolated and relatively rare habitat, the destruction of hundreds of acres of peatland in Park County, Colorado, has probably affected individuals and occurrences. Furthermore, the National Research Council's Committee on Mitigating Wetland Losses (2001) concluded that mitigation criteria required for compliance with the provisions of Section 404 of the Clean Water Act have often not been attained, in part because permit expectations were unclear and compliance was never monitored. The Committee also found that although progress has been made since the 1980's, the goal of "no net loss of wetlands" is not being met (National Research Council 2001). The Committee's report indicates that enforcement of current laws and regulations is inadequate to protect the unique habitat of *S. candida*.

Biology and Ecology

Classification and description

Salix candida is a member of the willow family (Salicaceae), which is generally regarded as consisting of the genera *Populus* and *Salix*. Treatments of Asian material recognize two additional genera, *Chosenia* and *Toisusu*, but these are not found in North America (Argus 1997). The genus *Salix* includes approximately 450 species worldwide; these are distributed primarily in the Northern Hemisphere (Argus 1997).

The classification of the genus *Salix* at a worldwide level has been fraught with confusion and discarded names. The primary difficulties have been the tendency for authors to produce regional or continental classifications rather than to treat the genus as a whole, and trouble in assembling a suite of characters that is useful for classification across the entire group. Argus (1997) provides a comprehensive review of classification efforts from Linnaeus to the present. Although the most recent treatment of the entire genus (Andersson 1868) is now well over a century old, it still provides the foundation for more recent treatments. The North American *Salix* were treated more recently by Dorn (1976) and later by Argus (1997), who recognized four subgenera and 28 sections of native species, three sections represented only by naturalized species, and a total of 104 species present in the New World. Dorn (1976) placed *S. candida* in subgenus *Vetrix*, section *Vimen*, whose other Rocky Mountain members are *S. planifolia* and *S. drummondiana*. In Region 2, persistent fruiting bracts characterize the subgenus *Vetrix* (Dorn 1997). Argus (1997) placed *S. candida* in the subgenus *Vetrix*, section *Candidae*. The other North American member of section *Candidae* is *S. wiegandii*. *Salix candida* is known by the common names sage willow, sage-leaved willow, hoary willow, and rarely, silver willow.

History of knowledge

The name *Salix candida* was attributed to Johannes Flüggé in Carl Ludwig von Willdenow's Edition Five of Species Plantarum (Vol 4(2):708, 1806). The 1892 Botanical Gazette citation given in Glisson (2003) is apparently a misprint as the article in question treats *Carex* species and does not mention *S. candida*. Nieuwland (1914) treated Indiana specimens as *S. candidula*, and alternative treatments include *S. candida* Flueggé ex Willd. var. *denudata* Anderss. and var. *tomentosa* Anderss. (USDA Natural Resources Conservation Service 2005), but these synonyms are not currently accepted as valid. No type specimen is known for *S. candida* (Dorn 1976). Hall and Harbour first collected *S. candida* in Region 2 during the Parry expedition of 1862, but the location is given only as "Colorado" (Coulter 1885). An undated collection by Drummond is labeled "Rocky Mountains," and it may have come from within Region 2. Most occurrences of *S. candida* have been discovered within the last 25 years, and new locations have been found as recently as 2005.

Description

The following description is based on Gleason and Cronquist (1963), Dorn (1997), Fertig (2000), and Argus (2001, 2004). *Salix candida* is a perennial, deciduous, low to mid-sized shrub with erect stems (Dorn 1997). It typically grows up to 1.5 m tall, but a few authors indicate that it may occasionally be taller (Dorn 1997). This species generally does not form colonies by layering (Argus 2001). Branches are flexible at the base and mostly smooth (glabrous); they lack the white waxy bloom typical of some *Salix* species. Young twigs are densely woolly with soft white hairs (described variously as lanate, floccose, pubescent, or tomentose). This woolliness may persist into the second year. The leaves are narrowly elliptic to narrowly ovate, with entire (not toothed), inrolled margins; they are 3 to 10 cm in length. The upper leaf surface is dark green with sparse wooly hairs, and the underside is densely white woolly hairy (**Figure 2**).

All *Salix* species are dioecious (i.e., male flowers and female flowers are produced on separate plants). *Salix* flowers are borne in catkins (also called aments). Catkins appear at the same time as or slightly before the leaves. Male (staminate) catkins of *S. candida* are densely flowered, 1 to 3 cm long, with two stamens per flower and reddish-purple anthers. Female (pistillate) catkins are somewhat longer, at 2 to 5 cm long, with woolly, tawny capsules, styles 0.3 to 1.9 mm long, and stipes 0.1 to 1.2 mm long, with pale bracts or scales below the flowers that are persistent in fruit. The fruits (capsules) are mostly 5 to 10 mm long when mature.

Salix candida is most likely to be confused with *S. brachycarpa*, which has leaves that are glaucous below and hairy on both surfaces, and has a similar low stature. At least one herbarium specimen from Idaho has both species on the same sheet. The leaves of *S. brachycarpa* are smaller and broader than those of *S. candida*. However, natural variation in growth may lead to some overlap between the species. *Salix drummondiana* also has similar long, narrow leaves with glaucous, densely hairy undersides, and darker green, sparsely hairy upper surfaces. In contrast to the densely woolly twigs of *S. candida*, the young twigs of *S. drummondiana* are typically pruinose, with a waxy, powdery, whitish coating on the surface.

Published descriptions and other sources

Pending the completion of the treatment of the genus *Salix* by Dr. G.W. Argus in the forthcoming Volume 7 of *The Flora of North America*, the most complete technical description of *S. candida* to date is found in Argus (2001). Other descriptions include, but are not limited to, Britton and Brown (1913), Smith (1942), Gleason and Cronquist (1963), Hitchcock and Cronquist (1973), Welsh (1974), Dorn (1997), and Argus (2004). Dichotomous keys providing less detailed descriptions are found in the regional floras

Figure 2. Leaves and fruiting catkins of *Salix candida* (left), and habit of *S. candida* (right). Photographs by Brian Elliott (left) and Susan Spackman Panjabi (right), used with permission.

including Great Plains Flora Association (1986), Dorn (2001), and Weber and Wittmann (2001). A drawing and photograph of the plant and its habitat are available in the *Colorado Rare Plant Field Guide* (Spackman et al. 1997), in both online and print versions. Additional illustrations or photographs are available in Britton and Brown (1913; **Figure 3**), Hitchcock and Cronquist (1973), Carter (1988), Dorn (1997), Colorado Native Plant Society (1997), Fertig (2000), and others.

Distribution and abundance

Salix candida is a boreal species whose distribution is concentrated in the northern tier of the United States, including Alaska, and in Canada from Newfoundland to British Columbia (Argus 2001, NatureServe 2006). The species is confined to North America; it does not occur in the boreal regions of other continents. In Region 2, occurrences are rare and scattered in South Dakota, Wyoming, and Colorado, where they are peripheral or disjunct from the more northern center of distribution (**Figure 1**, **Table 1**).

Although each of the several episodes of glaciation that occurred during the Quaternary (i.e., during the past 2 million years) affected the distribution of species, the last glacial maximum (the Wisconsinan) is the episode that contributed most to the definition of the distribution of modern North American biotas (Brouillet and Whetstone 1993). During the peak of the Wisconsinan glaciation about 18,000 years before the present, boreal forest communities dominated a band from the southern margin of the continental ice sheet to approximately 34º N latitude and extended across the Great Plains. Comparison of modern and fossil pollen assemblages indicates that these communities were similar in composition to modern boreal forest communities (Delcourt and Delcourt 1993). The southward retreat of boreal vegetation during the period of glacial increase resulted in colonization of patches of suitable habitat. Some boreal and alpine species, including *Salix candida*, remained in these refugia when the ice retreated and species' ranges again moved north (Gates 1993, Weber 2003).

The southern limit of *Salix candida* in Region 2 is 600 to 700 miles south of the main boreal distribution of the species. Known occurrences of *S. candida* in Region 2 are confined to about six centers of distribution separated by 100 to 300 miles. Within the distribution clusters, locations are separated by fewer than 50 miles. In South Dakota, *S. candida* is restricted to the northeastern corner of the state where it is adjacent to the main distribution of the species and a disjunct area

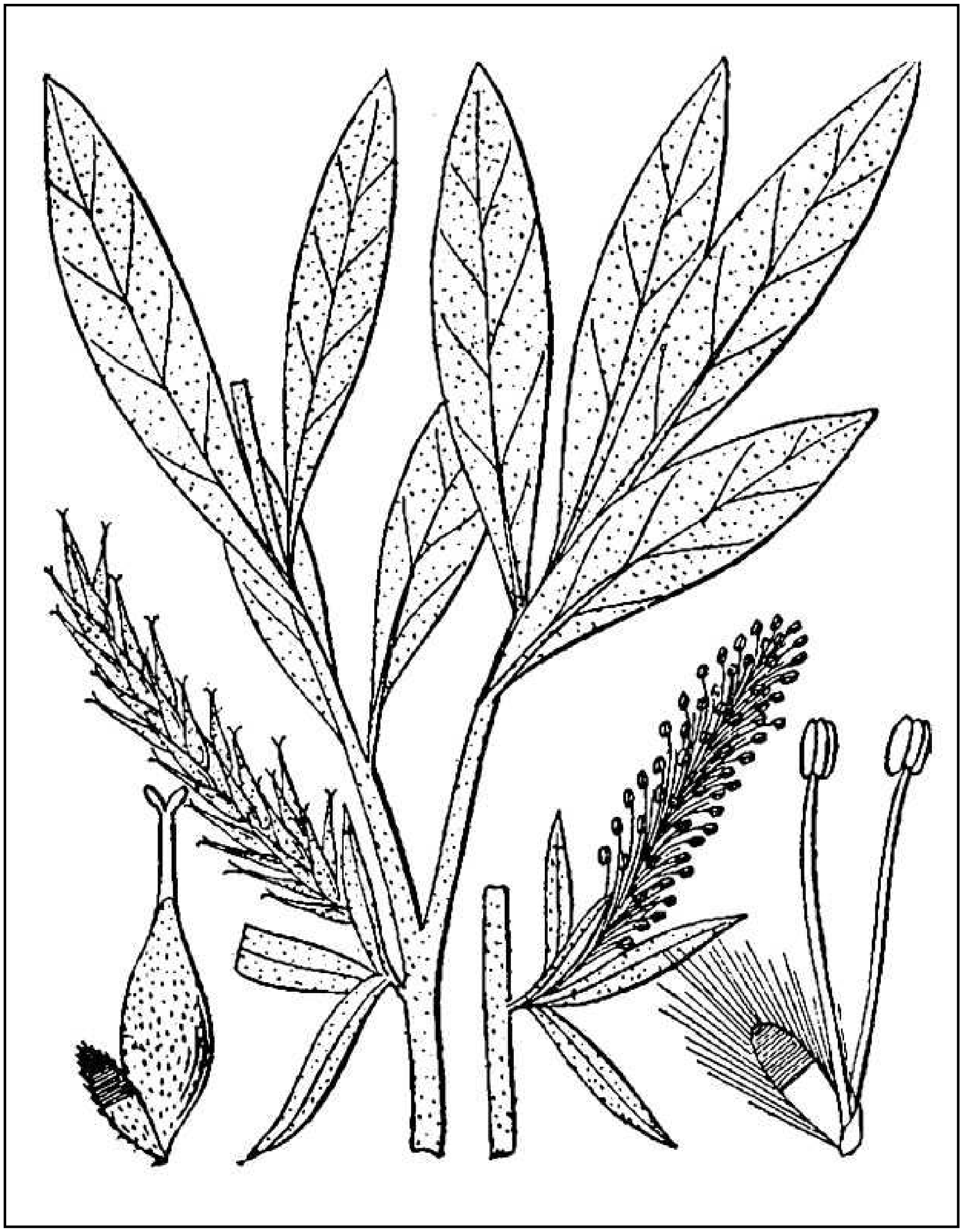


Figure 3. Illustration of *Salix candida* from Britton and Brown (1913). This image is not copyrighted and may be freely used for any purpose.

in the Black Hills. Wyoming locations are concentrated in the northwestern corner of the state (north and south of the Yellowstone valley) and in the Medicine Bow and Laramie ranges in the south-central part of the state. Colorado locations are concentrated in the high intermontane valley of South Park in the central part of the state. A location on the western slope of the adjacent Mosquito Range was discovered recently (Elliott personal communication 2005). A location in the upper Laramie River valley is best thought of as part of the southern Wyoming group of locations.

Although exact abundance figures are not available, *Salix candida* is considered secure or apparently secure where it occurs in the southern Canadian provinces from British Columbia to Newfoundland. Its status changes to vulnerable or imperiled at the edges of its distribution in Alaska and the Canadian Maritime Provinces and in the northern tier of United States from Washington to Maine.

Occurrence sizes have been reported for slightly more than half of the locations in Region 2. Where numbers have been reported (**Table 1**), occurrences are generally small to moderate in size, ranging from two to 5,000 individuals, with an average of around 500 plants. A conservative estimate of the total population in Region 2 is between 8,700 and 10,000 plants.

Population trend

Data that would allow a detailed description of population trends are generally lacking. Of the 32 occurrences in Region 2, only 12 have been clearly documented as having been visited multiples times, and none has been counted systematically more than once. Moreover, the long life span of *Salix candida* means that detection of population trends may require counts over long time periods. The few repeat observations that provide documentation of trend indicate that occurrences are either stable, slowly increasing, or slowly decreasing, with possible changes in numbers in the range of 10 to 100 individuals, although these numbers are probably within the margin of error. Population trends are also unknown for the main distribution of the species, but the global population is presumed to be stable, as demonstrated by the lack of conservation status ranks for the species in the central Canadian provinces. Due to the relative rarity of its habitat in Region 2, *S. candida* is likely to have always been an uncommon species in those states.

Habitat

Throughout its range, *Salix candida* is typically associated with fens, bogs, marshes, and other areas of permanently saturated soils where peat is present (**Figure 4**). These habitats often have high mineral content and alkaline pH (Lesica 1986, Cooper 1996) and are characterized as "rich" or "extreme rich" fens. Although *S. candida* has an affinity for nutrient-rich fens, it is able to tolerate a range of variation in peatland conditions, and range-wide habitat information does not support the conclusion that it is exclusive to rich fens.

Peatlands are generally defined as having at least 30 to 40 cm of peat accumulation, and they are imprecisely referred to as swamps, bogs, fens, moors, muskegs, or mires (Charman 2002). Two basic types of peatland are recognized:

1) bogs, defined as peatlands that receive water and nutrients solely from precipitation falling onto the surface, and that are generally acidic and nutrient poor
2) fens, defined as peatlands influenced by water from outside their limits (i.e., groundwater and surface runoff), and that are generally less acidic and more nutrient rich (Charman 2002).

All herbaceous peatlands in Region 2 are properly classified as fens, but there is a broad range in nutrient richness and hydrology (Cooper 1986, Cooper and Andrus 1994, Johnson 2000). Fens form at low points in the landscape or on gentle slopes where groundwater intercepts the soil surface. Groundwater inflows maintain a constant water level year-round, with water at or near the surface most of the time. Constant high water levels lead to an accumulation of organic material. In Region 2, fens are also often sites with a relatively high proportion of disjunct boreal or arctic species (Bedford and Godwin 2003).

Glisson (2003) and Hornbeck et al. (2003) described the McIntosh Fen complex (occurrence 20 in **Table 1**) in western South Dakota as a cold, permanently saturated wetland with an organic (peaty) substrate derived from the slow decay of grasses and sedges. This fen is enriched by spring water with high levels of calcium carbonate. Habitats descriptions are poorly documented for the remaining South Dakota locations, all of which are in the eastern part of the state. They appear to be typical calcareous fen communities of the Prairie Pothole Region. NatureServe (2006) includes these fens in the North-Central Interior Shrub-Graminoid Alkaline Fen Ecological System. The cold, anoxic, and circumneutral conditions of the water promote the accumulation of peat, and inhibit the growth of many species. Graminoids (e.g., *Carex prairea*, *Schoenoplectus pungens*, and *Rhynchospora capillacea*) dominate the vegetation, but it may contain small shrubs. *Salix candida* is characteristic of this community type. Elevations of occurrences in South Dakota are mostly unreported, but probably range between 5,000 and 6,410 ft. (1,525 and 1,950 m).

Salix candida occurrences in Wyoming are located in fens, often nutrient-enriched (Wyoming Natural Diversity Database 2006). The Swamp Lake location (occurrence 30 in **Table 1**) on the Shoshone National Forest is a large, extremely rich fen at the base of the Cathedral Cliffs in northwestern Wyoming. These cliffs contain limestone and dolomite that contribute to the calcareous nature of the water sources that maintain the fen. *Salix candida* is found in a variety of vegetation types throughout the fen, including floating mats of

(Left) Boston Peak Fen Research Natural Area, Arapaho Roosevelt National Forest, Colorado,. Photograph by Susan Spackman Panjabi, used with permission.

(Right) High Creek Fen, Colorado. Photograph from Colorado Natural Heritage Program files, used with permission.

(Left) South Fork South Platte Fen, Colorado. Photograph by Denise Culver, used with permission.

Figure 4. Habitat of *Salix candida*.

Carex simulata, marly hummocks of *Eleocharis* and *Triglochin*, *C. rostrata* marsh, *Picea glauca* swamp forest; and *Alnus* woodlands (Wyoming Natural Diversity Database 2006). The Sheep Mountain and Hecht Creek locations (occurrences 25 and 26 in **Table 1**) on the Medicine Bow National Forest are characterized as rich fens (Heidel and Laursen 2003a), both in headwater drainages on the granite escarpment of Sheep Mountain. The southern Sand Lake site (occurrence 28 in **Table 1**) on the Medicine Bow National Forest is believed to be a modified glacial kettle in glacial till that includes dolomite (Heidel and Laursen 2003a). Other Wyoming locations are fens that are not known to be nutrient-enriched. Wyoming elevations are intermediate in range for occurrences in Region 2, ranging from 6,600 to 9,220 ft. (2,010 to 2,810 m).

Colorado habitats of *Salix candida* are usually characterized as calcareous, rich, or extremely rich fens. An exception is the Boston Peak Fen (occurrence 2 in **Table 1**) on the Arapaho and Roosevelt National Forests, whose peat is enriched by uranium, not calcium carbonate (Owen and Otton 1995). In this location, the retreat of the Pinedale glaciation left lateral moraines on the valley walls, some of which subsequently slumped to the valley bottom. One such slump, 13,000 to 14,000 years ago, partially blocked the valley and led to the formation of the fen, trapping runoff from springs and seeps (Owen and Otton 1995, Coles 1997). Although peat deposits in the fen have high concentrations of uranium, bedrock and glacial deposits surrounding the fen do not. The remaining 14 Colorado occurrences of *S. candida* are concentrated in and around the high-elevation intermontane valley of South Park. In this area, calcareous bedrock, glacial history, climate, and hydrology combine to create wetlands rich in mineral nutrients ("extremely rich fens") that are unusual in the southern Rocky Mountains (Cooper 1990a, Carsey and Decker 1999). The cool climate and saturated soils of South Park produce the conditions necessary for the formation of layers of peat. The rate of peat accumulation in extremely rich fens is even slower than in the rich and intermediate fens found in other parts of Region 2. While rich fens accumulate 10 to 16 inches of peat in 1,000 years, the extremely rich fens of South Park accumulate only 4.3 inches in the same amount of time (Cooper 1990b). Colorado elevations are at the upper end of the range for *S. candida* in Region 2, at 8,900 to 10,040 ft. (2,710 to 3,060 m).

Salix candida is associated with the plant communities that are characteristic of enriched fens and saturated soils. Data from specimen labels and element occurrence records show it occurring with the species shown in **Table 2**. The high pH of rich fens limits the plants that are able to grow there, sometimes resulting in a suite of plant species that are locally or regionally rare (marked with * in **Table 2**). Most of these plants are rarely found south of the arctic, and they are believed to have been stranded in these wetlands at the end of the Pleistocene.

Although quantitative information on the physical and chemical characteristics of many *Salix candida* locations is lacking, the species appears to have an affinity for fens with neutral to basic pH levels, and saturated, peaty soils. Reported pH levels for some locations in Region 2 are 6.9 to 7.9 at Swamp Lake (Fertig and Jones 1992), 7.6 to 8.3 at High Creek Fen (Cooper 1996), 7.22 to 7.88 at Old Railroad/Antero, 7.65 to 7.9 at Crooked Creek Spring, 8.13 to 8.73 at Trout Creek, and 6.2 to 7.76 at Hollthusen Gulch/Tarryall Creek Fen (Cooper 1990a). *Salix candida* has been reported from a wide variety of fen microhabitat types, including water tracks, fen lawns and hummocks, quaking mats, short and tall willow carrs, and other peaty areas (Johnson and Steingraeber 2003, Glisson 2003, Colorado Natural Heritage Program 2006, Wyoming Natural Diversity Database 2006). It is most frequently reported as occurring with other shrubs on low hummocks above adjoining hollows or in fen meadows dominated by sedge vegetation (Lesica 1986, Johnson and Steingraeber 2003, Colorado Natural Heritage Program 2006, Wyoming Natural Diversity Database 2006). This type of microhabitat specialization along micro-relief, hydrologic, or chemical gradients is common among fen species (Sanderson and March 1996).

Reproductive biology and autecology

As a long-lived perennial species that devotes several years to vegetative growth before reproducing, *Salix candida* can be regarded as a *K*-selected species (MacArthur and Wilson 1967). Willows are often colonizers of disturbed riparian areas or floodplains, but non-riparian willows such as *S. candida* tend to occur in stable habitats (Kovalchik 2001), where they are best described as stress-tolerant in the strategic schema of Grime (2001). Although *S. candida* has some competitive and ruderal characters, most of its characteristics suggest elements of stress-tolerance (e.g., growing in waterlogged soils and low temperatures).

Salix candida primarily reproduces sexually by seed. Although most willows can be easily propagated from cuttings (Newsholme 1992), and broken or beaver-cut branches may root if forced into the ground, *S.*

Table 2. Species associated with *Salix candida* in USDA Forest Service Region 2.

Species name	SD	WY	CO	Species name	SD	WY	CO
Alnus spp.		X		*Packera pauciflora**			X
Betula nana (*Betula glandulosa*)		X	X	*Parnassia parviflora*			X
Betula pumila		X		*Picea glauca*		X	
Calamagrostis canadensis			X	*Picea pungens*			X
Calamagrostis stricta			X	*Poa pratensis*			X
Carex aquatilis	X	X	X	*Primula egaliksensis**			X
Carex interior	X			*Ptilagrostis mongholica* ssp. *porteri**			X
*Carex livida**			X	*Salix brachycarpa*			X
Carex nebraskensis	X			*Salix eriocephala* var. *ligulifolia*			X
Carex prairea	X			*Salix monticola*			X
*Carex scirpoidea**			X	*Salix myrtillifolia**		X	X
Carex simulata		X	X	*Salix phylicifolia*	X		
Carex utriculata (*Carex rostrata*)		X	X	*Salix planifolia*		X	X
*Carex viridula**			X	*Salix serissima**	X	X	X
Dasiphora floribunda	X	X	X	*Salix wolfii*		X	
Deschampsia caespitosa			X	*Sisyrinchium pallidum**			X
Eleocharis spp.		X	X	*Taraxacum officinale*			X
Eleocharis quinqueflora			X	*Thalictrum alpinum*			X
Hierochloe odorata	X			*Trichophorum pumilum**		X	X
Juncus balticus var. montanus			X	*Triglochin* spp.		X	
Kobresia myosuroides			X	*Typha* spp.	X		
*Kobresia simpliciuscula**		X	X	*Utricularia ochroleuca**			X
Lomatagonium rotatum			X				

*species considered rare in Region 2 by the Colorado Natural Heritage Program

candida does not tend to form large clones by layering (Argus 2001). Nearly all willows, including *S. candida*, are dioecious; a plant has either male flowers or female flowers, but not both. Worldwide, this sexual system is found in four percent of species (Yampolsky and Yampolsky 1922). Separate sexes may be advantageous because obligatory outcrossing allows dioecious species to avoid the negative effects of inbreeding depression (Baker 1959, Thomson and Barrett 1981). Alternative explanations (Charnov et al. 1976, Charnov 1982) are based on resource allocation models that focus on ecological and physiological conditions that could favor either hermaphroditism or dioecy (Thomson and Brunet 1990). An important implication of the dioecious condition is that in many species, males and females respond differently to environmental conditions (Bierzychudek and Eckhart 1988). This character could be important in evaluating the consequences of management actions. The investigation of sexual reproduction in flowering plants is complicated by the lack of stable sex-determining mechanisms in some plants and by the labile sex expression in many species. In addition, the production of mixed-sex catkins or fertile bisexual flowers has been occasionally observed in unseasonally flowering individuals (Smith 1942, Rohwer and Kubitzki 1984, Glisson 2003). This type of variable gender expression has not been reported in *S. candida*.

Catkins of *Salix candida* appear either with the leaves or slightly before (coetaneous flowering). In Region 2, *S. candida* begins flowering in May at lower elevations and in early June to late July at higher elevations of Colorado and Wyoming. At some locations, plants may continue flowering into August. Fruit set begins shortly after flowering and overlaps with it.

Most willows are thought to be primarily insect pollinated, but they also produce copious pollen that is wind dispersed (Karrenberg et al. 2002a). This mixed-pollination syndrome includes the presence of nectar production and floral scent to attract insect pollinators, as well as large amounts of small pollen and precocious flowering. Such mixed systems are thought to arise when the presence of insect pollinators is unpredictable. In the few species for which pollen vectors have been determined, the results vary from almost exclusive insect pollination to primarily wind pollination (Peeters and Totland 1999, Karrenberg et al. 2002b).

Karrenberg et al. (2002a) investigated pollen vectors in four floodplain willow species (*Salix alba*, *S. daphnoides*, *S. elaeagnos*, and *S. triandra*). Their results show that pollination is necessary for seed set (although seedless fruit developed in some instances), and that maximum seed set is associated with insect vectors. Reported insect visitors to *Salix* flowers include a variety of Dipteran, Hymenopteran, and Lepidopteran species (Sacchi and Price 1988, Totland and Sottocornola 2001, Karrenberg et al. 2002a). Pollen vectors for *S. candida* have not been investigated, but they are likely to be primarily insects that frequent peatland habitats. Wind pollination is a potential vector for gamete dispersal between some populations of *S. candida* in Region 2, but successful inter-population pollination is likely to be much less frequent than within-population anemophily.

Few specifics are known about the reproductive capacity of *Salix candida*. Willows are generally characterized as producing large numbers of seeds, but the total resources devoted to seed production may be much lower than that of annual species. Even when the percentage of filled seeds per catkin is low, the numbers of catkins produced can result in very large numbers of seeds per individual plant. In Karrenberg et al. (2002a), individuals produced several hundred to several thousand catkins. Catkins had between 35 and 150 fruits each, and fruits contained two to 22 seeds. The average number of seeds produced per individual over all four species was more than 200,000. Under laboratory conditions, germination rates for many *Salix* species are close to 100 percent, but temperature requirements vary (Densmore and Zasada 1983, Young and Clements 2003). Germination rates are typically lower under natural conditions. Sacchi and Price (1992) noted that *S. lasiolepis* (a floodplain species) reached seedling densities of up to 25,000 per square meter. Fertility and seed viability of *Salix* species can be high. Seed production and seedling survival, however, depend on a variety of factors including pollination rates, resource availability, and weather conditions.

A spreading coma of fine, silky hairs that are longer than the seed surround the seeds and facilitate dispersal by wind (Argus 1986). The 'drag chute' function of the coma allows the tiny seeds to gain altitude in gentle convective air currents, and spreading seed hairs allow many seeds to cluster together. When seeds are wetted, the hairs quickly collapse and release the seed (Karrenberg et al. 2002a). Although some species are also likely to be dispersed by water, this is not likely to be a primary dispersal mechanism in *Salix candida*.

Seedling mortality is likely high for *Salix candida*. Available research is primarily on floodplain species. Sacchi and Price (1992) recorded nearly 100 percent mortality of first year seedlings of *S. lasiolepis* in northern Arizona, and they found that the lack of soil surface moisture was the primary cause of seedling mortality. McBride and Strahan (1984) found similar results for *S. hindsiana* and *S. laevigata* in northern California. In peatland habitats, infrequent, localized disturbance (e.g., trampling by domestic or wild ungulates) produce rare open sites for establishment of seedlings. Although these gaps may positively affect the germination of many herbaceous fen species (Isselstein et al. 2002), Stammel and Kiehl (2004) found that species varied in their tolerance of the negative effects of trampling (e.g., soil compaction, changes in the availability of light and water). They concluded that gap creation by trampling may not be a suitable conservation tool for rare wetland species. Cottrell (1993, 1995) found that willow seedlings were only present in unvegetated peat, and that they were completely absent in the continuous sedge/willow cover of Rocky Mountain National Park willow carrs.

Salix species are often described as producing short-lived seeds that lack dormancy (e.g., Brinkman 1974, Raven 1992). Densmore and Zasada (1983) found that some northern *Salix* species disperse conventionally dormant seeds. Species dispersing seeds in summer produce short-lived, non-dormant seeds. Fall-dispersing species produce seeds that develop dormancy while still on the plant and are unable to germinate at the low temperatures that prevail once they are dispersed. Densmore and Zasada (1983) hypothesize that fall dispersal of dormant seeds is an adaptation to a short growing season in cold climates and evolved from non-dormant summer dispersing taxa. Both types of dispersal are represented in subgenus *Vetrix*, and *S. brachycarpa* and *S. glauca* (close relatives of *S. candida*) are fall dispersers. Seed dormancy for *S. candida* is unknown, but its long flowering period suggests that it may produce dormant seeds that cannot germinate until the next growing season.

Although synthetic hybrids are easily formed between many *Salix* species, natural hybridization in willows is apparently rare in North America (Argus 1974, Dorn 1976). There are numerous studies on synthetic hybrids, especially those involving *S. petiolaris*, *S. eriocephala*, and *S. sericea* (e.g., Hjältén 1998, Orians et al. 1999, Hochwender and Fritz 2004). Argus (1974) noted that the ease with which synthetic hybrids are created in experimental settings does not mean that natural hybrids are equally common. It can be difficult to distinguish hybrid individuals from natural phenotypic variation in this highly variable genus, and this may lead to the under-reporting of hybridization events (Hardig et al. 2000). However, this possibility should not become a *de facto* explanation for taxonomic issues in the genus without further investigation. Isolating mechanisms in *Salix* include differences in flowering time, habitats, and ploidy levels (Dorn 1976).

Notwithstanding the above caveat, there are a few legitimate instances of hybridization in *Salix candida*. In a population of *S. candida* near Ithaca, New York, Rowlee and Liegand (1896) described crosses with *S. petiolaris* and *S. cordata*. In addition, Argus (1997) indicated that the species described by Fernald (1933) as *Salix* x *wiegandii* originated as a hybrid between *S. candida* and *S. calcicola*. No hybrids have been reported from Region 2. Eight other *Salix* species have been reported as occurring with *S. candida* (**Table 2**), so the potential for hybridization exists. Most willows exhibit variation in vegetative characters such as plant stature, leaf size, shape, and hairiness in response to environmental variables such as moisture, nutrients, shade, and wind (Argus 2001). This variability makes it important to use mature, typical branches for identification.

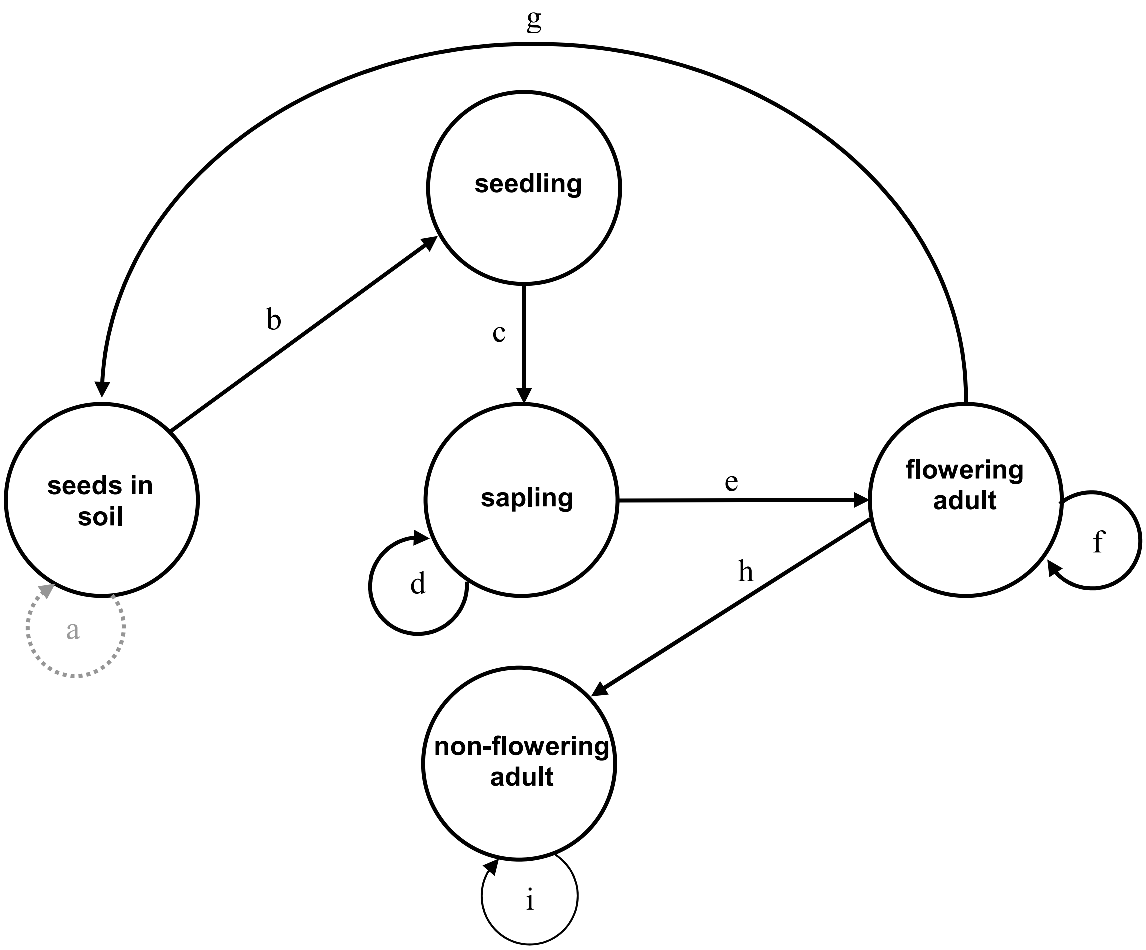
Endomycorrhizal fungi belonging to the taxonomic order Glomales are a key component of one of the most common underground symbioses. These endomycorrhizae are characterized by inter- and intracellular fungal growth in the root cortex where they form fungal structures known as vesicles and arbuscles (Quilambo 2003). Vesicular-arbuscular mycorrhizae (VAM) occur in about 80 percent of all vascular plants (Raven et al. 1986), and the association is geographically widespread. Association with VAM has been reported for a variety of *Salix* species (Harley and Harley 1987, Newman and Reddell 1987, Dhillion 1994). Ectomycorrhizal associations have also been reported in many *Salix* (Dhillion 1994, Thormann et al. 1999), and some species support both conditions simultaneously (Dhillion 1994). The mycorrhizal status of *S. candida* has not been investigated.

Demography

Recruitment, survival, reproductive age, and other vital rates for *Salix candida* are unknown. Demographic studies in *Salix* are primarily of floodplain species. Population dynamics of floodplain willows are heavily influenced by periodic flood events that allow recruitment of more or less distinct cohorts (e.g., Merigliano 1998), resulting in large groups of individuals of the same age class. For plants of saturated ground, such as *S. candida*, disturbance events that allow recruitment are not necessarily tied to hydrologic events, and do not necessarily allow the establishment of cohorts. Mortality of established plants is presumably much lower than that of seedlings, and once established, plants are likely to survive for decades. Age at first flowering can be as low as two years for colonizing riparian species like *S. exigua* (Ottenbreit and Staniforth 1992); other species require up to ten years before becoming reproductive (Haeussler and Coates 1986). **Figure 5** shows a hypothetical life cycle diagram for *S. candida*. Because there are no studies of *S. candida*, transition probabilities are left unquantified.

Although small, isolated occurrences face numerous potential problems, studies have concluded that these locations can still be viable conservation targets (Lesica and Allendorf 1992, 1995, Lammi et al. 1999, Matthies et al. 2004). The minimum viable population (MVP) is the smallest population that is predicted to have a reasonable chance of survival for the near future (Primak 1995). Estimates for MVP vary, according to different types of uncertainty affecting populations (e.g., demographic stochasticity, environmental stochasticity, large-scale natural catastrophe, and genetic stochasticity; see Shaffer 1981) Suggested MVP numbers range from 50 to buffer demographic stochasticity and 500 to buffer genetic stochasticity (Franklin 1980), to a range of 1000 to 1,000,000 to guard against extinction due to environmental stochasticity and natural catastrophes (Menges 1991).

The range in MVP estimates highlights the potential utility of Population Viability Analysis (PVA) models with robust parameters that are developed for an individual species. Such analyses require substantial empirical data and an understanding of the links among environmental variability, demography, and genetics in the species of interest (Menges 1991). Impacts of demographic, environmental, and genetic stochasticities on *Salix candida* are unknown, but they are important considerations in conservation,



a. survival of dormant seeds in the seed bank (possibly none)
b. probability of seed becoming a seedling (extremely low)
c. survival of seedling to juvenile, pre-reproductive stage (low)
d. probability of juvenile remaining non-reproductive
e. probability of juvenile plant becoming reproductive
f. probability of flowering adult flowering again next year
g. seed production of flowering plants
h. probability of flowering adult not flowering next year
i. probability of non-flowering adult remaining non-flowering

Figure 5. Life-cycle diagram for *Salix candida* (after Caswell 2001).

management, and restoration planning. There are no PVA models available for *S. candida*. Morris et al. (1999) discuss general classes of data sets and methods suitable for PVA, including:

- ❖ count-based extinction analysis, which requires counts of individuals in a single population from censuses performed for a minimum of 10 years (preferably more)
- ❖ multi-site extinction analysis, which requires counts from multiple populations, including a multi-year census from at least one of those populations
- ❖ projection matrix modeling, which requires detailed demographic information on individuals collected for three or more years, typically at only one or two sites.

Currently there are no data sets available that could be used for PVA of *S. candida*. Basic studies of life cycle stages of *S. candida* would greatly facilitate viability analysis.

Community ecology

The community ecology of *Salix candida* encompasses its interactions with populations of co-existing species, including competition for resources, the effects of herbivory, parasites, and disease, and any mutualistic or symbiotic interactions. Effects of competition and herbivory have not been investigated in *S. candida*, but some inferences can be made from studies of its congeners, and from its association with peatland communities. Peatland habitats are often densely vegetated, and species may have highly specialized niches along a micro-topographic or hydrologic gradient. However, mixed willow stands are common in *S. candida* occurrences, and any micro-topographic or hydrologic requirements that separate *S. candida* from other willows and peatland vegetation are unknown. The tendency for peatland species to rely on disturbance to open sites for seedling establishment means that *S. candida* is likely to be in competition with other peatland plants for this resource.

Herbivory on *Salix candida* has not been explicitly documented, but some specimens have been annotated as "heavily browsed," and plants at some locations have been reported as being reduced to very low stature (several inches high) by browsing. Other species of *Salix* are known to be subject to herbivory. *Salix* species are often key structural components of wetland and riparian habitats, so the effects of grazing or browsing by domestic livestock, wild ungulates, beaver, and small mammals have been studied for numerous species. Documented effects of vertebrate herbivory on willows include reduced aboveground biomass, height, survival, and sexual reproduction, as well as changes in plant morphology, and population age and size structure (Schulz and Leininger 1990, Maschinski 2001, Brookshire et al. 2002, Holland 2002). These effects can be seen in some instances even under relatively light levels of grazing (Brookshire et al. 2002), and they may remain evident many years after the removal of livestock (Holland 2002). Effects of herbivory are generally related to the duration of exposure to herbivory, the amount of herbivore-free recovery time, and the numbers and kinds of herbivores present (Maschinski 2001, Baker et al. 2005). Trampling by large herbivores may contribute to the formation of open sites for seedling establishment, but it may also have a detrimental effect on the hydrology, microtopography, and canopy structure of the habitat (Stammel and Kiehl 2004).

Willows are also subject to attack by a variety of insect herbivores (e.g., Stein et al. 1992, Kendall et al. 1996, Sipura 2002). The genus *Salix* apparently displays the spectrum of strategies between resistance to and tolerance of herbivory. Plants that develop chemical defenses (resistance) against herbivory are presumed to pay a price in reduced growth, while plants that evolve tolerance to herbivory escape the metabolic costs of manufacturing secondary compounds and instead spend resources on regrowth. The rapid regrowth of some pioneering willow species is interpreted as tolerance to herbivory (e.g., Kudo 2003), while the characteristic phenolic glucoside salicylate produced by many *Salix* species acts as a defense against herbivory (e.g., Kendall et al. 1996). The strategy employed by *S. candida* is not known.

Nearly all *Salix* species have some degree of susceptibility to infection by fungal rust belonging to the *Melampsora epitea* species complex (Smith et al. 2004). However, resistance to infection is highly variable among species and pathogen populations (Pei et al. 2004). In one experiment, *S. candida* was highly resistant to European forms of the pathogen (Pei et al. 2004), but its resistance to North American strains is not known. There are no reports of fungal infection of *S. candida* occurrences in Region 2. Willows are also susceptible to a variety of insect borers and gall-forming species (e.g., Froiland 1962, Collet 2002, Sipura 2002), but there are no reports of infections of *S. candida* in Region 2.

CONSERVATION

There have been no studies of the effects of management activities or natural disturbances on *Salix candida*, but some inferences can be drawn from knowledge of its preferred fen habitat. *Salix candida* depends on a functional hydrologic regime to persist. Any management activity or natural disturbance that disrupts the hydrologic dynamics of its habitat is likely to have an effect on habitat quality. In general, management activities or natural disturbances that affect habitats are likely to have similar or parallel effects on individuals or occurrences. In particular, hydrological modification associated with road building, livestock grazing, motorized vehicle use, or peat mining is likely to have a direct impact on individuals and occurrences of *S. candida*. These activities may kill or damage plants, and population remnants are not necessarily able to recolonize disturbed areas. Surface disturbance may also affect the survival and reproductive success of individuals by altering local patterns of erosion and drainage and eliminating safe sites for germination.

There are no known commercial uses for *Salix candida* other than as incidental forage for domestic grazers. *Salix candida* is occasionally collected in botanical surveys, but it has never been the subject of formal scientific investigation in Region 2. There is no evidence to suggest that past levels of collecting have endangered any occurrences, and limited collecting for research purposes could be approved whenever it will enhance current knowledge of the abundance and distribution of *S. candida*.

Threats

Based on available information, there are several threats to the persistence of *Salix candida* in Region 2. In approximate order of decreasing concern, these include hydrologic alterations, global climate change, grazing, road construction/maintenance, peat mining, impacts from recreational use, consequences arising from small population sizes, alteration of natural fire regime, and invasive species.

Altered hydrology

Due to the apparent restriction of *Salix candida* to fen and related peatland habitats, hydrologic alteration is the foremost threat to the species, and this threat interacts to some degree with other threats. Any alteration that disrupts saturated soils and the formation of peat is likely to have a negative impact on *S. candida*. Changes in hydrologic regime can influence nutrient cycles, sedimentation, fragmentation, and habitat quality in wetland systems. Hydrologic alteration can result from natural and human impacts to watersheds supporting *S. candida* occurrences, including water diversion or development, local agricultural use, long-term drought, changes in beaver populations, and high tree density in adjacent uplands (Charman 2002). Because fens supporting *S. candida* are part of large-scale hydrologic systems, they may be affected by distant diversions or pumping as well (Woods 2000).

In addition to their direct effects on populations and individual plants, other threats, such as grazing, road construction activities, peat mining, recreational use, and global climate change, can influence the hydrology of *Salix candida* habitat. For example, fluctuations of lake and groundwater water levels created by trenching and ditching due to grazing or water diversion have dramatically altered vegetation at Hager Lake Fen in Idaho (Bursik and Moseley 1992). Bursik and Moseley (1992) also found that environmental variables such as logging, fire, and grazing affected the chemistry of surface and substrate waters. These activities are also likely to increase nutrient runoff into fens (Bursik 1993).

Many of the *Salix candida* locations in Region 2 have experienced hydrological alterations. At McIntosh Fen in the Black Hills, the current extent of the fen is smaller than it was when originally reported, due to the effects of drainage ditches that were dug when the area was privately owned (Glisson 2003). Hydrologic conditions at other South Dakota locations are unknown, but they may have been impacted by adjacent agricultural land use.

Hydrological modifications of Wyoming locations appear to be primarily the result of road placement or construction activities. The placement of a highway culvert above the previous water level of the Swamp Lake fen altered the site's hydrology. This apparently led to additional prolonged inundation of portions of the fen, including areas where *Salix candida* was documented (Heidel and Laursen 2003b). The Crow Creek and Sand Lake Road fens have raised roadbeds on at least one margin, and the proximity of this barrier is likely to have some impact on the hydrology of the peatlands (Heidel and Laursen 2003a). Other Wyoming locations are not known to have extensive hydrological modifications.

In Colorado, a road bisects the Lake County fen, but the hydrological impacts are unknown (Elliott personal communication 2005). Site hydrology of the Boston Peak fen area in Larimer County is believed to be essentially intact (Coles 1997) in spite of a recent vehicular incursion (see Recreational Use below). Most of the wetlands in South Park have been subject to some hydrological modification. Irrigation of hay meadows and the consequent dewatering of streams have rearranged the distribution of wetlands on the landscape (Cooper 1990a). Most *Salix candida* locations in South Park are known to have hydrological alterations.

In the High Creek area of South Park, which includes three occurrences of *Salix candida* (High Creek Fen, High Creek North of Black Mountain, and High Creek at Warm Spring), ditches divert water upstream of the occurrences (Spackman et al. 2001). The Fremont ditch cuts across the slope at the lower end of the Hollthusen Gulch/Tarryall Creek fen, and it apparently isolates the fen from Tarryall Creek. Groundwater hydrology, however, is believed to be sufficient to maintain the fen elements if no additional water manipulation occurs (Sanderson and March 1996). A ditch also crosses the lower end of the Crooked Creek site. While the ditch has dried out the lower portion of the fen, the hydrology of the upper portion of the site does not appear to be adversely affected (Sanderson and March 1996). Hay meadow irrigation has altered the Jefferson and Guernsey creeks area. Although this irrigation creates more wetland area, the irrigated areas do not support extremely rich fen species such as *S. candida*. To date, the irrigation diversions at the site do not appear to have significantly impacted site hydrology (Spackman et al. 2001). The Trout Creek location is also irrigated (Cooper 1990a), but the overall effect on site hydrology is unknown. At the Old Railroad site near Antero Reservoir, site hydrology has been altered by a railroad grade across the fen and by upstream diversions (Sanderson and March 1996). The proposed expansion of Antero Reservoir also threatens this site, which would be inundated by higher storage levels (Denver Water Board Citizens Advisory Committee 2004). Water development also potentially threatens the Geneva Park site, which has been proposed as a potential reservoir site (USDA Forest Service, Pike and San Isabel National Forests no date) but is not currently listed on the Colorado Dam Site Inventory (Colorado Water Conservation Board 2000). Both the Geneva Park and Duck Creek sites are adjacent to the Guanella Pass Road; effects of the road on site hydrology are unknown. Site hydrology for the South Fork South Platte and Sheep Creek sites is believed to be intact, and the upstream Twelve Mile Creek location is likely to be in similar condition.

Hydrological alterations due to residential development of South Park are a particular threat to *Salix candida* locations in that area. During the period 1990 to 2000, the population of Park County grew at an annual average rate of 7.3 percent, and similar growth is expected through 2020 (Pikes Peak Area Council of Governments 2003). Under the combination of steady development and continuing drought, the area has seen increased reliance on groundwater pumping to supply local requirements (Pikes Peak Area Council of Governments 2003). In the mid-1990's, the South Park Conjunctive Use Project proposed to draw water from creeks and from the water table under the wetlands in South Park to supply the city of Aurora in the Denver Metro area with 20,000 acre-feet of water per year (Federal Register: February 4, 2005 - Volume 70, Number 23). Models of the potential effects of this project predicted groundwater drawdown across much of the north end of the Park ranging from 0.5 ft. to many tens or even hundreds of feet (Sanderson personal communication 2006). Sanderson's (2000) assessment of the potential effects of this drawdown on another fen species (*Ptilagrostis porteri*) concluded that because many wetland plants are sensitive to drawdown of 0.5 ft. or less, groundwater withdrawals could seriously damage fens in South Park. The South Park Conjunctive Use Project proposal was ultimately defeated, but growing water requirements along the Colorado Front Range mean that similar proposals may appear in the future. This is a potential long-term threat to the quality and persistence of habitat for *S. candida* in South Park.

Global climate change

Although global climate change is potentially the most serious threat to the persistence of *Salix candida* in Region 2, there is great uncertainty regarding its regional effects and severity. For example, the effects of global climate change on *S. candida* in Region 2 will not necessarily be the same as in its main distribution in the northern reaches of the continent (Gates 1993). Although global climate change is likely to have wide-ranging effects in the near future for all habitats, changes will be most obvious in ecosystems where the structure and composition are strongly influenced by limiting conditions of temperature or rainfall (Walker 1991), such as peatlands. Peters and Lovejoy (1992) summarized characteristics of species or populations that are expected to be most susceptible to climate change: 1) peripheral populations at the edge of a shrinking species' range, 2) geographically localized species, 3) highly specialized species, 4) poor dispersers, 5) montane and alpine communities, 6) arctic communities, and 7) coastal communities. Populations of *S. candida* in Region 2 have specialized habitat requirements (often in montane zones) and are certainly peripheral to the main range.

Predicted effects of climate change include loss of species diversity, changes in phenology, increases in incidence of species invasions or disease, and changes in correlations between ecological factors that are important for species survival (Gates 1993, McCarty 2001, Walther et al. 2002). Temperature changes due to climate change could also alter the duration and frequency of insect herbivory for many species (Bale et al. 2002). For *Salix candida*, climate change is most likely to have an impact through changes in hydrology and temperature that affect local nutrient and moisture availability as well as the physical process of peat formation, rather than a direct limiting effect on individual plants (Charman 2002). Finally, the effects of climate change could result in shifts in vegetation dominance that will eventually eliminate *S. candida* from its habitat. If *S. candida* populations are unable to colonize other suitable areas within the region, this threat has the potential to eliminate the species from Region 2.

Grazing

Major impacts of grazing include removal and reduction of vegetation, soil compaction, and increased erosion. These impacts have been shown to affect biodiversity, hydrology, water chemistry, and other variables (Menke 1977, Johnston and Brown 1979, Chadde et al. 1998). Pearson and Leoschke (1992) found that grazing modified the structure of the fen plant community through selective utilization of plant species and altered the physical structure of the wetland by trampling. Grazing animals can create paths in peaty soils, thus channelizing water that would otherwise move through the sloped peatlands in a sheet fashion (Windell et al. 1986, Chadde et al. 1998, Bursik 1993). If the grazing regime is intense enough to produce channelization, these habitats may dry out, and cattle use will further increase (Bursik 1993). Severe grazing can also result in the destruction of individuals plants.

Grazing by domestic livestock has been observed at several *Salix candida* locations in Region 2, and all Region 2 occurrences are likely to be grazed by native herbivores. Grazing of domestic livestock is not permitted in the fen portion of the SIA at McIntosh Fen on the Black Hills National Forest (Glisson 2003). The area was historically subject to trespass grazing (Hornbeck et al. 2003). Grazing status of South Dakota occurrences on private lands is unknown.

On the Shoshone National Forest, the Swamp Lake Botanical Area is off-limits to grazing, but it is not fenced to exclude livestock; the Lily Lake site is part of an active grazing allotment (Houston personal communication 2005). On the Medicine Bow National Forest, the Sheep Mountain and Hecht Creek locations are part of the Sheep Mountain Game Refuge, where domestic livestock grazing is not permitted, but pack animals may graze (Heidel and Laursen 2003a). The other locations on the Medicine Bow National Forest are within active cattle grazing allotments (USDA Forest Service, Medicine Bow National Forest 2003). Heidel and Laursen (2003a) report that in some parts of the Crow Creek peatland in Wyoming, nearly half of the herbaceous vegetation had been removed by livestock grazing. Heidel and Laursen (2003a) also attributed shifts in vegetation composition at the site to trampling and other indirect effects of grazing.

In Colorado, the grazing allotment containing the Boston Peak Fen RNA on the Arapaho-Roosevelt National Forest was vacant at time of RNA establishment, and the area is not expected to be grazed unless required as a management technique. On the Pike-San Isabel National Forest, the Lake County location is not on an active grazing allotment (Elliott personal communication 2005). The portion of the Crooked Creek site that is on National Forest System lands is in an allotment that has been vacant since 1992 (Lamb personal communication 2005). The Geneva Park and Duck Creek locations are on an active allotment that is grazed for three weeks annually where the stocking rate has been permanently reduced by half since 2001 (Lamb personal communication 2005). Domestic livestock grazing rates for locations on private lands are not known in detail. Most private occurrences are exposed to grazing by domestic cattle, and the nearby High Creek Fen occurrence has been subject to trespass grazing (Spackman et al. 2001). Grazing is heavy at some locations; at the South Fork South Platte fen, some plants were reported to be grazed down to a few inches high in 1995 (Colorado Natural Heritage Program 2006).

For Region 2 occurrences that are grazed, the degree of impact to *Salix candida* individuals at those locations is generally not known. Significant removal of aboveground biomass of *S. candida* and undefined shifts in vegetation composition have been reported; monitoring is needed to determine the long-term consequences of this type of disturbance.

Road construction and maintenance

Roads and trails impact wetlands by affecting key physical processes such as water runoff and sediment yield. Roads, even at some distance from a wetland, can concentrate water flows, increase flow rate, increase erosion, and reduce percolation and aquifer recharge rates (Forman and Alexander 1998). The McIntosh Fen occurrence on the Black Hills National Forest is near roads that may indirectly affect hydrological flows, but road construction is prohibited in the Botanical Area (Glisson 2003). With the exception of the two occurrences on the Sheep Mountain Game Refuge, all Wyoming occurrences of *Salix candida* are within 0.2 miles of roads. The Wyoming occurrence on the North Branch of Crow Creek is the most directly threatened by road building (Heidel and Laursen 2003a). In Colorado, the Geneva Park and Duck Creek occurrences along the Guanella Pass Road are most directly affected by roads. The southern Lake County occurrence is also next to a road (Elliott personal communication 2005). In general, roads do not directly threaten other Colorado occurrences, except as they might modify nearby hydrology. In most cases, the presence of roads can also facilitate the spread of invasive species.

Peat mining

Every peat mining operation in Colorado has destroyed habitat for rare plant species as well as associated plants (Sanderson personal communication 2006). There is little evidence that this habitat can be restored to its former state, nor that rare plants can be induced to re-colonize mined areas (Sanderson et al. in prep). Peat mining severely alters hydrology, interrupting the sheet flow of water that maintains peat formation. Peat mining also reduces vegetation cover and species richness, alters species composition, eliminates microtopography, and alters edaphic properties. These effects generally change soil and groundwater chemistry, seriously impairing wetland functioning (Johnson 2000). Due to its slow accumulation rates (20 to 28 cm per 1,000 years; Cooper 1986), peat in Region 2 cannot be considered a renewable resource.

Colorado is the only area in Region 2 where commercial peat mining is permitted and is ongoing (USDI Bureau of Mines 1994, Austin personal communication 2004). Sanderson and March (1996) calculated that almost 20 percent of South Park's pre-settlement fen acreage has been destroyed by peat mining. At least six *Salix candida* locations in Colorado have been subject to peat mining: Geneva Park, High Creek at Warm Spring, High Creek Fen, Old Railroad/Antero, South Fork South Platte, and Wahl/Coleman Ranch (Colorado Natural Heritage Program 2006). At the Old Railroad/Antero location, extensive mining essentially destroyed half the wetland. Peat mining is not known to be affecting any of the documented occurrences of *S. candida* in Region 2 currently. *Salix candida* occurrences on private lands with substantial peat deposits are potentially threatened by peat mining activities.

Recreational use

Recreational use can potentially damage or destroy individual plants or entire populations. The most likely location for recreational impacts to *Salix candida* occurrences on National Forest System lands is the Geneva Park area, which is heavily used by campers, hikers, and hunters, and where *S. candida* individuals are in close proximity to roads. Recreational use is of concern primarily for locations on public lands, and on private lands where access by recreational or roadway users is not controlled. Threats from this type of activity vary with the type and intensity of use. The most serious threat is from illegal off-road vehicle use of wetlands, a practice known as mud-bogging. In April 2003, mud-boggers essentially destroyed a one-acre wetland on the Medicine Bow National Forest (Casper Star-Tribune, April 17, 2003). In 2004, mud-boggers apparently created two pits in the Boston Peak Fen site. These open muddy areas are attractive to moose (*Alces alces*), who use them as wallows (Popovich personal communication 2006). This threat is difficult to predict and to control. Wetlands may also be damaged by off-road vehicle users who are not specifically seeking muddy conditions. *Salix candida* habitat that is in close proximity to roads is likely to be at increased risk of vehicle trespass, but the prevalence of off-highway vehicle use on public lands throughout Region 2 means that most wetlands on public lands are potentially at risk. Other impacts from recreation result from trampling or trail-making by hikers, fishers, hunters, or pack stock.

Fire

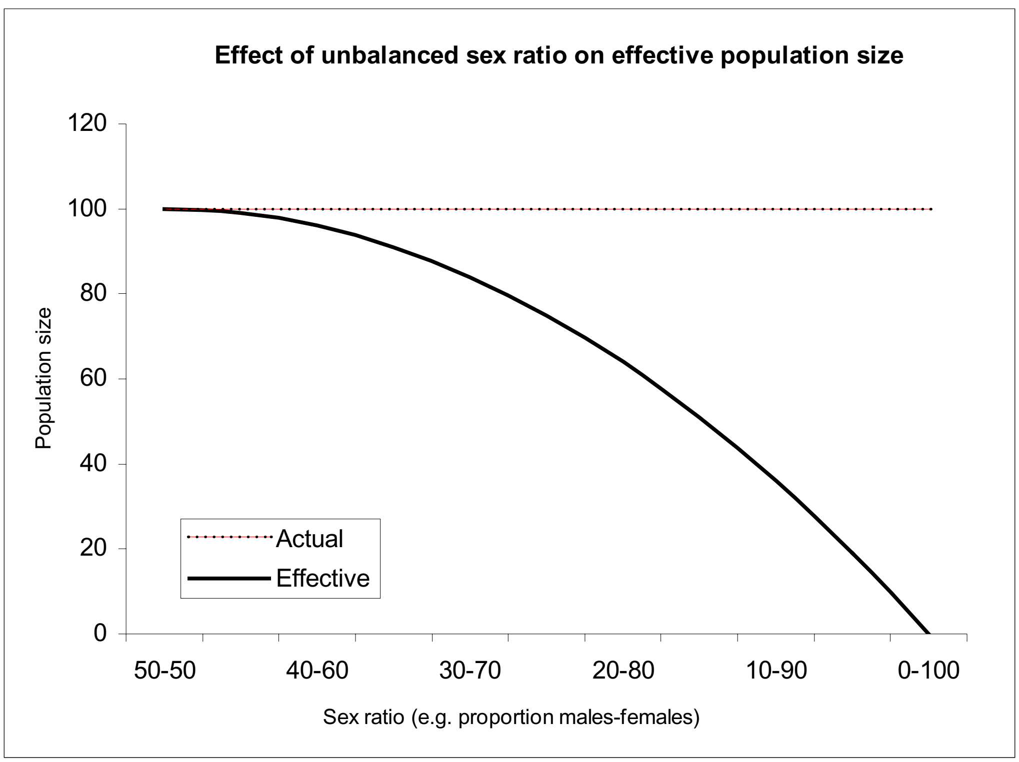
In general, the wetness of peatlands means that they are less susceptible to fire than the surrounding landscape; however, dry summer conditions can allow top layers of peat to burn (Charman 2002). In boreal fen systems, fire is an important mechanism maintaining non-forested open wetland conditions and preventing the drying-out of fen habitat, but fire return intervals are generally long (Charman 2002). Fire frequency and severity are likely to be different for occurrences of *Salix candida* in Region 2 than for occurrences in the heart of its range. Fire suppression and the subsequent increase of woody vegetation in surrounding uplands can affect the hydrology of peatland habitat. Conversely, a rare catastrophic fire could easily damage or destroy a small occurrence of *S. candida*. The plants may be able to resprout, however, if not killed. One documented effect of fire at the Swamp Lake Botanical Area is the occurrence of debris flows into the fen from destabilized cliff faces where a crown fire destroyed the forest (Heidel and Laursen 2003b). Although such flows may destroy or damage some individuals, they are probably not a threat to the entire occurrence. There are no other instances where documented occurrences in Region 2 are known to have been affected by fire.

Small population effects

Many *Salix candida* occurrences in Region 2 are small enough for the consequences of demographic, environmental, or genetic stochasticity to be important considerations. In small populations, the effects of these processes are higher relative to larger populations.

Reported numbers of individuals at several *Salix candida* occurrences in Region 2 appear to be sufficient to buffer against the probability that a fluctuation in vital rates (i.e., demographic stochasticity) will take the occurrence to the extinction threshold. For many occurrences, the number of plants present is unknown. A few occurrences are below the generally accepted minimum of 50 individuals. As a dioecious plant, *S. candida* is also vulnerable to chance variation in the sex ratio that could reduce effective population sizes (Hartl and Clark 1989), or even eliminate one sex from the population altogether. For dioecious species, any deviation of the sex ratio from 1:1 reduces the effective population size (**Figure 6**). A smaller effective population size increases the potential for inbreeding, genetic drift, and other consequences. Although sex ratios are not known for any *S. candida* occurrences, at least one other sensitive *Salix* species in Region 2 (*S. myrtillifolia*) has an occurrence consisting of only female plants (Neid et al. 2004), and the possibility of a similar situation for *S. candida* cannot be ruled out. This type of demographic stochasticity could eliminate a few of the smallest *S. candida* occurrences but is not likely to be a threat to the species' persistence in Region 2.

Environmental stochasticity generally refers to variation over time in the physical and biological environment. Changing environmental conditions, such as weather, herbivory, and pollinator availability, can lead to local extinction (Lande 1998, Oostermeijer et al. 2003). Natural events at random intervals resulting in the deaths of a large proportion of individuals in the population are also a potential concern for small, isolated *Salix candida* occurrences. Such events may occur very rarely, yet still have a large effect on the persistence of the population (Menges 1991). For *S. candida*, potentially important environmental events might include catastrophic fire, landslide, or extreme drought. Multiple populations



Effective population size (N_e) calculated as $N_e = \frac{4N_{males}N_{females}}{N_{males} + N_{females}}$ (Hartl and Clark 1989)

Figure 6. Effect of unbalanced sex ratio on effective population size.

can have a mitigating effect against the operation of environmental stochasticity.

The potential genetic consequences of small population size include increased inbreeding, loss of genetic variation due to genetic drift, and the accumulation of deleterious mutations (Matthies et al. 2004). Inbreeding depression, or a loss of fitness due to decreased heterozygosity, results from an increased number of matings between closely related individuals. Although inbreeding through selfing is not a concern for *Salix candida*, in isolated populations matings are necessarily between individuals that are more closely related than are two random members of the species. It is not clear that metapopulation dynamics are operating between the isolated distribution centers of Region 2; within these centers (especially in South Park), it is possible that gene flow is occurring between occurrences. In isolated populations, immigration of seeds or pollen from other population does not mitigate the loss of genetic variation by drift (Oostermeijer et al. 2003). Due to the distances involved, there is probably very little gene flow between most population centers of *S. candida* in Region 2. Some insect pollinators are capable of flight distances of 10 to 50 miles (Janzen 1971, Ghazoul 2005), but this has not been investigated for pollinators of *S. candida*. Because *S. candida* is primarily insect pollinated, pollinator-mediated gene flow is unlikely between occurrences that are separated by distances of more than a few dozen miles. Even wind-dispersed pollen is not usually transported far from its source (Levin and Kerster 1974).

Invasive species

Direct impacts to *Salix candida* from invasive species have not been reported, and the magnitude of this threat is not known. In the Black Hills National Forest, Canada thistle (*Cirsium arvense*), butter-and-eggs (*Linaria vulgaris*), and houndstongue (*Cynoglossum officinale*) are known to occur near the McIntosh Fen occurrence (Hornbeck et al. 2003). There is a risk that restoration of the hydrology at this site may make it vulnerable to invasion by purple loosestrife (*Lythrum salicaria*), which has been documented near Rapid City, 20 to 25 miles east of McIntosh Fen (Hornbeck et al. 2003). Invasive species impacts for other South Dakota locations are unknown, but herbicide spraying may have indirectly affected at least one location. Wyoming locations remain largely free of exotic species (Wyoming Natural Diversity Database 2006). The proximity to roads of several Wyoming sites increases their vulnerablity to the spread of invasive species from elsewhere. The only Colorado location potentially threatened by the expansion of non-native species is High Creek Fen, where a small patch of Canada thistle has been documented (Spackman et al. 2001).

Conservation Status of Salix candida in Region 2

A lack of repeat observations of *Salix candida* occurrences and the continuing discovery of new occurrences make it difficult to give a firm estimate of the distribution and abundance of the species in Region 2. There is no evidence that its distribution or abundance in Region 2 is declining. There is likewise no evidence that populations are expanding. The current perception of the insecure status of this species in Region 2 arises from the low number of occurrences, the rarity of its habitat, and the disjunct or peripheral nature of the occurrences.

Salix candida is tied to a small-patch type of habitat that is found only in a narrow range of environmental conditions, where it is often isolated from similar habitat on the landscape. Moreover, occurrences in Region 2 at the edge of the normal range are probably found in environmental conditions that would be atypical compared to those experienced by occurrences further north. The current distribution and abundance of *S. candida* in Region 2 are primarily the legacy of the retreat of glacial conditions of the Pleistocene. As glaciation ended, *S. candida*, along with many other species of boreal habitats, generally migrated north following the retreating ice. In a few isolated locations, local conditions allowed the persistence of relictual occurrences. These glacial disjuncts are now isolated both from each other and from the central range of the species. Ultimately, the survival of these species in Region 2 habitats depends on climatic trends as well as on the conservation efforts of land managers and owners. A steady but gradual loss of occurrences over time could lead to a contraction of the species' range and a loss of population viability within that range. It is important for managers and planners to be mindful of the cumulative effect of the threats described above.

Management of Salix candida in Region 2

Implications and potential conservation elements

There is no documentation of the consequences of historic, ongoing, or proposed management activities on the abundance and distribution of *Salix candida*. Although current knowledge of the distribution and abundance of *S. candida* in Region 2 suggests that the species' persistence is precarious in the Region due to its specialization on a relatively rare habitat and small number of disjunct occurrences, additional information is needed to clarify its status. We also know very little about patterns of abundance throughout the main part of the species' range, which makes it difficult to determine the importance of the Region 2 occurrences.

Disjunct and peripheral populations of *Salix candida* are of interest to conservationists even when the survival of the species does not depend on these populations. *Salix candida* is part of a unique relictual post-glacial community that provides key information about the Quaternary natural history of the North American continent. Peripheral populations may be important as genetic reserves since outlying populations sometimes contain atypical genetic variation in response to more difficult environmental conditions at the edge of the species' ecological range (Lesica and Allendorf 1995). Peripheral and disjunct populations provide an important resource for research in biogeography, metapopulation dynamics, and population genetics.

Occurrences in Region 2 are vulnerable to changes in the environment that affect their peatland habitat. Desired environmental conditions for *Salix candida* include an intact natural hydrological regime with little or no evidence of hydrologic alteration, anthropogenic nutrient inputs, or mining (especially peat mining). Conservation management for *S. candida* may require regulation and monitoring of hydrological modifications and restoration of water tables and drainages. Changes in management practices for livestock, fire suppression, logging, mining, and road construction, may also be required, as well as control of invasive species. Management activities may need to include adjacent land use.

Hydrological modifications are pervasive throughout the range of *Salix candida*. Natural environmental changes may also affect the peatland habitat favored by *S. candida*. Changes in precipitation patterns and effects of natural disturbances elsewhere in the watershed may lead to altered hydrology that is detrimental to the persistence of the species. In these instances, management policy could focus on mitigating these effects where feasible.

The establishment of protected areas managed for the conservation of *Salix candida* is a useful conservation strategy for this species. Management of the Black Hills site could be modified to include consideration of *S. candida* as well as *S. serissima*. Designation of Special Interest Areas or Research Natural Areas for the best occurrences on the Medicine Bow National Forest could help to ensure the protection of this species on National Forest System lands in Wyoming. Although most of the largest and highest quality occurrences in Colorado are not on National Forest System land, there is some opportunity to protect the species in Park County through careful management of recreation in the Geneva Park area. Additional information on occurrence sizes and trends is needed to determine the conservation importance of occurrences on National Forest System lands in Wyoming and Colorado.

Tools and practices

Tools available to the USFS for conservation of *Salix candida* in Region 2 include maintaining it on the regional sensitive species list, regulating the use of National Forest System lands where it occurs, and increasing the protection of *S. candida* occurrences. Implementation of these and other tools largely depends on the acquisition of better information on known or suspected occurrences. Censuses and trend observations of known occurrences are a priority for *S. candida*, because they will clarify the relative importance of known occurrences to conservation of the species in Region 2.

Species and habitat inventory

Inventories will be most effective during the flowering and fruiting season that is appropriate for the elevation of the site, especially when the sex of individual *Salix candida* plants can be determined. A census of targeted occurrences to determine the numbers and sexes of individuals present is required. For occurrences whose exact location is uncertain, the acquisition of precise locational data would be helpful in tracking population trends in Region 2, and in determining management responsibility. Initial searches will be most successful if they concentrate on similar habitat near known occurrences. Search areas can be closely linked to digital, georeferenced data, especially aerial photographs (both visual spectrum and infrared images), detailed soil maps, and vegetation maps, when available. Locations of known occurrences overlaid on aerial imagery would provide a quick method of identifying the extent of similar habitat in the areas where *S. candida* has been documented. This information can be cross-checked and augmented with the expert knowledge of agency personnel who are familiar with the area.

Existing protocols for species inventory are primarily based on surveys for rare, threatened, or endangered species. The following guidelines are adapted from U.S. Fish and Wildlife Service (2000), California Native Plant Society (2001), and Cypher (2002). Areas with the highest likelihood of new occurrences are those with appropriate hydrologic and edaphic qualities, especially peatlands that have not been previously inventoried. The use of aerial photography, topographic maps, soil maps, and geology maps to refine search areas when conducting inventories of large areas can be highly effective. It is most successful for species about which we have basic knowledge of its substrate (i.e., peatlands) and habitat specificity, from which distribution patterns and potential search areas can be deduced. Trained professionals who are familiar with the taxa in question should conduct the surveys. In addition, USFS personnel who visit likely habitat in the course of other work can be trained to check for the presence of *Salix candida*, and to record possible occurrences carefully. The return from the effort invested in species inventory can be maximized by careful documentation of results. Personnel for the initial survey need to be familiar with methods of soil and habitat characterization. A survey report will document the location that was visited, the date of the visit, the number and condition of individuals in the occurrence, habitat and associated species information, evidence of disease or predation, and any other pertinent observations. Surveyors are encouraged to use Global Positioning System (GPS) technology for quick and accurate data collection of location and occurrence extent. If a new occurrence of *S. candida* is located, a completed element occurrence report form for the appropriate state, accompanied by a copy of the appropriate portion of a 7.5-minute topographic map with the occurrence mapped, should be submitted to the appropriate state Natural Heritage Program. Mapping occurrence boundaries as accurately as possible will greatly facilitate relocation. If the population size permits, it is appropriate to collect voucher specimens and to submit them to regional herbaria. Voucher photographs may also be taken. Occurrences located on National Forest System lands can be permanently marked to facilitate population monitoring. The use of multiple monuments (e.g., corner stakes) and GPS coordinates can be a great help in relocating occurrences. Surveyors should also document areas that were searched unsuccessfully, but it is important to note that negative results are not a guarantee that the plant is absent from an area.

The value of surveys can be enhanced by sharing conclusions about the need for further inventory, the extent of the population, and critical habitat characteristics among state and federal agencies, natural heritage programs, local and regional experts, and interested members of the public.

Surveys usually attempt to target all species of concern in an area. In the case of inventory for *Salix candida*, this practice is particularly apt since there are typically other rare species in the peatland habitats that support *S. candida*. Although peatlands are significant biodiversity resources, there is no regional inventory of peatlands (Heidel and Laursen 2003a). A regional peatland inventory could provide habitat information for multiple species of concern. Although a complete inventory of peatlands in Region 2 would be a major undertaking, an effort similar to that of Chadde et al. (1998) in the Northern Rocky Mountains could be useful.

Population and habitat monitoring

Population trend monitoring could also be an important tool for the conservation of *Salix candida*. In order to be effective, researchers must clearly state monitoring goals and objectives and use repeatable methods focused on collecting data that reveal trends. Additionally, the implementation of monitoring must be accompanied by a resolve to adjust management practices based on the results. This monitoring could be combined with research on the biology and demography of the species. The apparent small size of many known occurrences means that it may be possible to monitor all individuals, and even to collect demographic data with slight additional effort. The first year of monitoring is likely to concentrate on establishing the timing of critical seasonal elements such as flowering and fruit set, and on determining the most useful and practical data collection protocols. Subsequent years could concentrate on collecting data at these established times.

Habitat monitoring can be conducted concurrently with population monitoring in peatlands that support *Salix candida*. Because the peatland habitat of *S. candida* often supports other regionally rare species and communities, habitat monitoring would be the most efficient way to detect impacts and population trends for a suite of important resources. Monitoring soil moisture, water table, and water chemistry would be useful for this species since it relies on a narrow range of environmental conditions. Documenting the scope and severity of disturbance in monitored occurrences would also be useful. Correlation of this information with population trends would greatly augment our present understanding of the habitat requirements and management needs of *S. candida*.

Habitat monitoring of known occurrences will alert managers to damage from anthropogenic activities or grazing, and allow management changes to be implemented in time to prevent serious damage to occurrences. Change in environmental variables might not cause observable demographic repercussions for several years, so resampling the chosen variables may help to identify underlying causes of population trends. Geographic Information System (GIS) technology can provide a powerful tool in the analysis of the scope and severity of habitat impacts. Alternatively, the use of photopoints for habitat monitoring is a powerful technique that can be done quickly in the field. Elzinga et al. (1998) describes this monitoring method, and Hall (2001) exhaustively covers practical details.

Seed banking and restoration methods

No seeds or genetic materials are currently in storage for *Salix candida* at the National Center for Genetic Resource Preservation (Miller personal communication 2005). *Salix candida* is not part of the National Collection of Endangered Plants maintained by the Center for Plant Conservation (Center for Plant Conservation 2004). Determination of the dormancy status of *S. candida* seeds will have important implications for the potential preservation of its genetic diversity through seed storage. Restoration methods have not been developed specifically for *S. candida*. The location at McIntosh Fen in the Black Hills has been the subject of restoration efforts focused on *S. serissima* (Hornbeck et al. 2003). It is not known if these efforts are also beneficial to *S. candida*.

Information Needs

The greatest information need for *Salix candida* is the determination of population numbers and trends over time for known occurrences throughout the region. It would also be useful to survey for additional occurrences, especially on public lands. A periodic, region-wide, interagency review of the species' status would greatly enhance conservation efforts. Basic life-history information, including the possibility of seed dormancy, rates of recruitment and survival, the effects of disease and insect outbreaks, and genetic variation in Region 2 occurrences, would also contribute to conservation and restoration efforts.

DEFINITIONS

Ament – same as catkin.

Calcareous – characterized by the presence of calcium carbonate.

Catkin – an inflorescence consisting of a dense spike or raceme of apetalous, unisexual flowers (Harris and Harris 1994).

Cohort – as used in this document, a group of individual plants that became established in the same year.

Congener – a member of the same genus.

Demographic stochasticity – chance variation in demographic rates (e.g., reproduction and mortality).

Dioecious, dioecy – plant breeding system in which male and female reproductive structures are borne on different plants (Allaby 1998).

Disjunct – occurring in two or more widely separated geographic areas (Weber and Wittmann 2001).

Effective population size – the size of an ideal population (i.e., one that meets all the Hardy-Weinberg assumptions) that has the same properties with respect to genetic drift as that of the observed population; usually smaller than the observed population size.

Environmental stochasticity – random year-to-year variation in birth and death rates in response to weather, disease, competition, predation, or other factors external to a population,

Extremely rich fen – A type of fen whose pH and calcium concentration values are on the upper end of the continuous range of fen variation, generally fens with pH >7 and calcium concentration >20 to 30 mg/l.

Floccose – having tufts of long, soft hairs (Harris and Harris 1994).

Genetic stochasticity – chance variation in gene frequencies within a population (i.e., genetic drift).

Glaucous – having a whitish or bluish, usually waxy coating (Harris and Harris 1994).

Hermaphroditism – the condition of having both male and female reproductive structures present in the same individual.

Heterozygosity – A measure of genetic diversity within and between populations, expressed as the frequency of having two different alleles of the same gene across individuals.

Inbreeding depression – a decrease in vigor among offspring after inbreeding, due to an increase in the homozygous expression of deleterious genes.

K-selected species – relatively long-lived species that produces only a few, often fairly large progeny.

Labile – easily changing.

Lanate – densely covered with long tangled hairs, woolly (Harris and Harris 1994).

Layering – vegetative propagation that occurs when branches that have been forced into the ground form roots.

Outcrossing – mating between unrelated individuals.

Peripheral – marginal, at the edge of the range or distribution.

Ploidy – the number of complete sets of chromosomes in a cell.

Precocious – of flowers, emerging before leaves are developed.

Potential Conservation Area (PCA) – a best estimate of the primary area supporting the long-term survival of targeted species or natural communities. PCAs are circumscribed for planning purposes only (Colorado Natural Heritage Program Site Committee 2002).

Pruinose – having a whitish waxy or powdery coating on the surface (Harris and Harris 1994).

Pubescent – hairy (Weber and Wittmann 2001).

Rank – used by Natural Heritage Programs, Natural Heritage Inventories, Natural Diversity Databases, and NatureServe. Global imperilment (G) ranks are based on the range-wide status of a species. State-province imperilment (S) ranks are based on the status of a species in an individual state or province. State-province and Global ranks are denoted, respectively, with an "S" or a "G" followed by a character (NatureServe 2006). *These ranks should not be interpreted as legal designations*.

Refugia – Places harboring species that have becoming extinct elsewhere.

Rich fen – A type of fen that has a middle range of pH (generally >5.7) and calcium concentration (>10 mg/l) in comparison with poor fens (more acidic) and extremely rich fens (more alkaline).

Stochasticity – random processes, governed by chance.

Sympatric – applied to species whose habitats (ranges) overlap (Allaby 1998).

Tomentose – having a dense covering of short, matted or tangled, soft woolly hairs (Harris and Harris 1994).

References

Allaby, M. 1998. A Dictionary of Plant Sciences. Oxford University Press. New York, NY.

Andersson, N.J. 1868. Salices Boreali-Americanae. A Synopsis of North American Willows. Cambridge, New York, NY.

Argus, G.W. 1974. An experimental study of hybridization and pollination in *Salix* (willow). Canadian Journal of Botany 52:1613-1619.

Argus, G.W. 1986. The genus *Salix* (Salicaceae) in the southeastern United States. American Society of Plant Taxonomists: Systematic Botany Monographs, Volume 9.

Argus, G.W. 1997. Infrageneric classification of *Salix* (Salicaceae) in the New World. American Society of Plant Taxonomists: Systematic Botany Monographs, Volume 52.

Argus, G.W. 2001. A Guide to the identification of willows in Alaska, the Yukon Territory and adjacent regions. Workshop on willow identification. George W. Argus, Ontario, Canada.

Argus, G.W. 2004. The interactive identification of native and naturalized New World *Salix* using INTKEY (Delta). Available online at: www.uaa.alaska.edu/enri/willow/index.html.

Austin, G. 2004. Personal communication with Range Management Specialist, Gunnison National Forest regarding peat mining in Region 2.

Baker, B.W., H.C. Ducharme, D.C.S. Mitchell, T.R. Stanley, and H.R. Pienetti. 2005. Interaction of beaver and elk herbivory reduces standing crop of willow. Ecological Applications 15:110-118.

Baker, H.G. 1959. Reproductive methods as factors in speciation in flowering plants. Cold Spring Harbor Symp. Quant. Biol. 24:177-191.

Bale, J.S., G.J. Masters, I.D. Hodkinson, C. Awmack, T.M. Bezemer, V.K. Brown, J. Butterfield, A. Buse, J.C. Coulson, J. Farrar, J.E.G. Good, R. Harrington, S. Hartley, T.H. Jones, R.L. Lindroth, M.C. Press, I. Symrnioudis, A.D. Watt, and J.B. Whittaker. 2002. Herbivory in global climate change research: direct effects of rising temperature on insect herbivores. Global Change Biology 8:1-16.

Bedford, B.L. and K.S. Godwin. 2003. Fens of the United States: distribution, characteristics, and scientific connection versus legal isolation. Wetlands 23:608-629.

Benedict, A.D. 1991. A Sierra Club Naturalist's Guide: The Southern Rockies. Sierra Club Books, San Francisco, CA.

Bierzychudek, P. and V. Eckhart. 1998. Spatial segregation of the sexes of dioecious plants. American Naturalist 132: 34-43.

Brinkman, K.A. 1974. *Salix* L. Willow. *In*: C.S. Schopmeyer, editor. Seeds of Woody Plants in the United States. Agriculture Handbook No. 450. USDA Forest Service, Washington, D.C.

Britton, N.L. and A. Brown. 1913. An Illustrated Flora of the Northern United States and Canada. 3 vol. Dover Publications, Inc., New York, NY. 2052 pp.

Brookshire, E.N., J. Brookshire, J.B. Kauffman, D. Lytjen, and N. Otting. 2002. Cumulative effects of wild ungulate and livestock herbivory on riparian willow. Oecologia 132:559-566.

Brouillet, L. and R.D. Whetstone. 1993. Climate and Physiography of North America. Chapter 1 *in* Flora of North America Editorial Committee, editors. Flora of North America North of Mexico. New York and Oxford.

Bursik, R.J. 1993. Fen vegetation and rare plant population monitoring in Cow Creek Meadows and Smith Creek Research Natural Area, Selkirk Mountains, Idaho. Report prepared for the Idaho Department of Fish and Game, Boise, ID by Conservation Data Center, Boise, ID.

Bursik, R.J. and R.K. Moseley. 1992. Forty-year changes in Hager Lake Fen, Bonner County, ID. Report prepared for the Idaho Department of Fish and Game, Boise, ID by Conservation Data Center, Boise, ID.

California Native Plant Society. 2001. Botanical Survey Guidelines of the California Native Plant Society. Fremontia 29:64-65.

Carey, T.T. 2006. Personal communication with Chief, Denver Regulatory Office, Omaha District, U.S. Army Corps of Engineers, regarding peat mining in South Park.

Carsey, K. and K. Decker. 1999. Identification and evaluation of wetlands of statewide significance in Colorado, 1998-1999. Final report to the EPA. Colorado Natural Areas Program, Denver, CO.

Carter, J.L. 1988. Trees and shrubs of Colorado. Johnson Books, Boulder, CO.

Casper Star-Tribune. 2003. "Mud-boggers tear up Vedauwoo." Available online at: http://www.casperstartribune.net/archives.

Caswell, H. 2001. Matrix Population Models. Second edition. Sinauer Associates, Inc. Sunderland, MA.

Center for Plant Conservation. 2004. National Collection of Endangered Plants. Database available online at: http://www.mobot.org/CPC/NC_choice.html.

Chadde, S.W., J.S. Sheely, R.J. Bursik, R.K. Moseley, A.G. Evenden, M. Mantas, F. Rabe, and B. Heidel. 1998. Peatlands on National Forests of the Northern Rocky Mountains; Ecology and Conservation. General Technical Report, RMRS-GTR-11, Rocky Mtn. Research Station, Ogden, UT.

Charman, D. 2002. Peatlands and Environmental Change. John Wiley & Sons, New York, NY.

Charnov, E.L. 1982. The theory of sex allocation. Monographs in population biology vol. 18, Princeton University Press, Princeton, NJ.

Charnov, E.L., J.M. Smith, and J.J. Bull. 1976. Why be an hermaphrodite? Nature 263:125-126.

Coles, J. 1997. Establishment record for Boston Peak Fen Research Natural Area. Prepared for the USDA Forest Service, Arapaho-Roosevelt National Forest by the Colorado Natural Areas Program, Colorado State Parks, Colorado Department of Natural Resources, Denver, CO.

Collet, D.M. 2002. Willows of south-central Alaska. Kenai Watershed Forum. Available online at: http://web.acsalaska.net/~kenaiwatershed.forum/willowguide.html.

Colorado Native Plant Society. 1997. Rare plants of Colorado. Second edition. Falcon Press, Helena, MT.

Colorado Natural Heritage Program Site Committee. 2002. Recommendations for Development and Standardization of Potential Conservation Areas and Network of Conservation Areas. Colorado Natural Heritage Program, Colorado State University, Fort Collins, CO.

Colorado Natural Heritage Program. 2006. Biodiversity Tracking and Conservation System, element occurrence records for *Salix candida*. Colorado Natural Heritage Program, Colorado State University, Fort Collins, CO.

Colorado Water Conservation Board. 2000. Colorado Dam Site Inventory. Available online at: http://cwcb.state.co.us/damsites/Introduction.htm.

Cooper, D.J. 1986. Community structure and classification of Rocky Mountain wetlands. *In*: J.T. Windell and B.E. Willard, editors. An ecological characterization of Rocky Mountain montane and subalpine wetlands. U.S. Department of the Interior, Fish and Wildlife Service, Biological Report No. 86(11):66-147.

Cooper, D.J. 1990a. Ecological studies of wetlands in South Park, Colorado: Classification, functional assessment, rare species inventory, and the effects of removing irrigation. Unpublished report prepared for Park County, Colorado and the U.S. EPA Region VIII.

Cooper, D.J. 1990b. An evaluation of the effects of peat mining on wetlands in Park County, Colorado. Unpublished report prepared for Park County, Colorado. 31 pp.

Cooper, D.J. 1996. Water and soil chemistry, floristics, and phytosociology of the extreme rich High Creek fen, in South Park, Colorado, U.S.A. Canadian Journal of Botany 74:1801-1811.

Cooper, D.J. and R. Andrus. 1994. Patterns of vegetation and water chemistry in peatlands of the west-central Wind River Range, Wyoming. Canadian Journal Botany 72:1586-1597.

Cottrell, T.R. 1993. The comparative ecology of *Salix planifolia* and *Salix monticola* in Rocky Mountain National Park. Ph.D. dissertation, Department of Biology, Colorado State University, Fort Collins, CO.

Cottrell, T.R. 1995. Willow colonization of Rocky Mountain mires. Canadian Journal of Forest Research 25:215-222.

Coulter, J.M. 1885. Manual of the botany (Phaenogamia and Pteridophyta) of the Rocky Mountain Region, from New Mexico to the British boundary. American Book Co., New York, NY.

Cypher, E.A. 2002. General rare plant survey guidelines. California State University, Stanislaus, CA. Endangered Species Recovery Program. Available online at: http://sacramento.fws.gov/es/documents/rare_plant_protocol.pdf.

Delcourt, P.A. and H.R. Delcourt. 1993. Paleoclimates, Paleovegetation, and Paleofloras of North America North of Mexico During the Late Quaternary. Chapter 4 *in* Flora of North America Editorial Committee, editors. Flora of North America North of Mexico. New York and Oxford.

Densmore, R. and J. Zasada. 1983. Seed dispersal and dormancy patterns in northern willows: ecological and evolutionary significance. Canadian Journal of Botany 61:3207-3216.

Denver Water Board Citizens Advisory Committee. 2004. Committee meeting minutes of June 17, 2004. Available online at: http://www.denverwater.org/cac/minutes/MINS_6-17-04.html.

Dhillion, S.S. 1994. Ectomycorrhizae, arbuscular mycorrhizae, and *Rhizoctonia* sp. of alpine and boreal *Salix* spp. in Norway. Arctic and Alpine Research. 26:304-307.

Dorn, R.D. 1976. A synopsis of American *Salix*. Canadian Journal of Botany 54:2769-2789.

Dorn, R.D. 1997. Rocky Mountain Region Willow Identification Field Guide. USDA Forest Service, R2-RR-97-01.

Dorn, R.D. 2001. Vascular Plants of Wyoming, Third edition. Mountain West Publishing, Cheyenne, WY.

Elliot, B. 2004. Personal communication with USFS Botanist, San Isabel National Forest regarding *Salix candida*.

Elzinga, C.L., D.W. Salzer, and J.W. Willoughby. 1998. Measuring and Monitoring Plant Populations. BLM Technical Reference 1730-1.

Fernald, M.L. 1933. Recent discoveries in the Newfoundland flora. Rhodora 35:230-247.

Fertig, W. 2000. *Salix candida* State Species Abstract. Wyoming Natural Diversity Database, Laramie, WY.

Fertig, W. and G. Jones. 1992. Plant communities and rare plant species of the Swamp Lake Botanical Area, Clark's Fork Ranger District, Shoshone National Forest. Wyoming Natural Diversity Database, Laramie, WY.

Forman, R.T.T. and L.E. Alexander. 1998. Roads and their major ecological impacts. Annual Review of Ecology and Systematics 29:207-231.

Froiland, S.G. 1962. The genus *Salix* (Willows) in the Black Hills of South Dakota. Forest Service. Technical Bulletin No. 1269. U.S. Department of Agriculture, Forest Service, Fort Collins, CO.

Gates, D.M. 1993. Climate Change and its Biological Consequences. Sinauer Associates, Inc. Sunderland, MA.

Ghazoul, J. 2005. Pollen and seed dispersal among dispersed plants. Biological Reviews 80:413-443.

Gleason, H.A. and A. Cronquist. 1963. Manual of vascular plants of Northeastern United States and adjacent Canada. Van Nostrand, Princeton, NJ.

Glisson, B.T. 2003. Conservation Assessment of Hoary Willow in the Black Hills National Forest, South Dakota and Wyoming. USDA Forest Service, Rocky Mountain Region, Black Hills National Forest, Custer, SD.

Great Plains Flora Association. 1986. Flora of the Great Plains. University Press of Kansas, Lawrence, KS.

Grime, J.P. 2001. Plant Strategies, Vegetation Processes, and Ecosystem Properties. John Wiley & Sons, Chichester, West Sussex, England.

Haeussler, S. and D. Coates. 1986. Autecological characteristics of selected species that compete with conifers in British Columbia: A literature review. Information Services Branch, Ministry of Forests, Victoria, BC, Canada.

Hall, F.C. 2001. Ground-Based Photographic Monitoring. General Technical Report PNW-GTR-503 USDA Forest Service Pacific Northwest Research Station, Portland, OR.

Hardig, T.M., S.J. Brunsfeld, R.S. Fritz, M. Morgan, and C.M. Orians. 2000. Morphological and molecular evidence for hybridization and introgression in a willow (*Salix*) hybrid zone. Molecular Ecology 9:9-24.

Harley, J.L. and E.L. Harley. 1987. A check-list of mycorrhiza in the British flora. New Phytologist (Suppl.) 105:1-102.

Harris, J.G. and M.W. Harris. 1994. Plant Identification Terminology. An Illustrated Glossary. Spring Lake Publishing, Spring Lake, UT.

Hartl, D.L. and A.G. Clark. 1989. Principles of Population Genetics, second edition. Sinauer Associates Inc., Sunderland, MA.

Heidel, B. and S. Laursen. 2003a. Botanical and ecological inventory of peatland sites on the Medicine Bow National Forest. Wyoming Natural Diversity Database, Laramie, WY.

Heidel, B. and S. Laursen. 2003b. Botanical and ecological inventory of peatland sites on the Shoshone National Forest. Wyoming Natural Diversity Database, Laramie, WY.

Hitchcock, C.L. and A. Cronquist. 1973. Flora of the Pacific Northwest, an illustrated manual. University of Washington Press, Seattle, WA.

Hjältén, J. 1998. An experimental test of hybrid resistance to insects and pathogens using *Salix caprea*, *S. repens*, and their F1 hybrids. Oecologia 117:127-132.

Hochwender, C.G. and R.S. Fritz. 2004. Plant genetic differences influence herbivore community structure: evidence from a hybrid willow system. Oecologia 138:547-557.

Holland, K.A. 2002. Grazing and exclusion affects willow growth in a montane riparian ecosystem. M.S. Thesis. Colorado State University, Fort Collins, CO.

Hornbeck, J.H., C.H. Sieg, and D.J. Reyher. 2003. Conservation Assessment for the Autumn Willow in the Black Hills National Forest, South Dakota and Wyoming. USDA Forest Service, Rocky Mountain Region, Black Hills National Forest, Custer, SD.

Houston, K.E. 2005. Personal communication with USFS Soils Scientist regarding *Salix candida*.

Huenneke, L.F. 1991. Ecological implications of genetic variation in plant populations. Chapter 2 *in* D.A. Falk and K.E. Holsinger, editors. Genetics and Conservation of Rare Plants. Oxford University Press, New York, NY.

Isselstein, J., J.R.B. Tallowin, and R.E.N. Smith. 2002. Factors affecting seed germination and seedling establishment of fen-meadow species. Restoration Ecology 10:173-184.

Janzen, D.H. 1971. Euglossine bees as long-distance pollinators of tropical plants. Science 171:203-205.

Johnson, J.B. 2000. The ecology of calcareous fens in Park County, CO. PhD. Dissertation. Department of Biology, Colorado State University, Fort Collins, CO.

Johnson, J.B. and D.A. Steingraeber. 2003. The vegetation and ecological gradients of calcareous mires in the South Park valley, Colorado. Canadian Journal of Botany 81:201-219.

Johnston, R.S. and R.W. Brown. 1979. Hydrologic aspects related to the management of alpine areas. Pages 65-70 *in* Special management needs of alpine ecosystems. USDA Forest Service General Technical Report R672.

Karrenberg, S., P.J. Edwards, and J. Kollmann. 2002a. The life history of Salicaceae living in the active zone of floodplains. Freshwater Biology 47:73-748.

Karrenberg, S., J. Kollmann, and P.J. Edwards. 2002b. Pollen vectors and inflorescence morphology in four species of *Salix*. Plant Systematics and Evolution 235:181-188.

Kendall, D.A., T. Hunter, G.M. Arnold, J. Liggitt, T. Morris, and C.W. Wiltshire. 1996. Susceptibility of willow clones (*Salix* spp) to herbivory by *Phyllodecta vulgatissima* (L) and *Galerucella lineola* (Fab) (Coleoptera, Chrysomelidae). Annals of Applied Biology 129:379-390.

Kovalchik, B.L. 2001. Classification and management of aquatic, riparian, and wetland sites on the National Forests of eastern Washington (Part 1: The series descriptions). Final Draft.

Kudo, G. 2003. Variations in leaf traits and susceptibility to insect herbivory within a *Salix miyabeana* population under field conditions. Plant Ecology 169:61-69.

Lamb, S. 2005. Personal communication with USFS Range Management Specialist/Botanist regarding grazing allotments and *Salix candida*.

Lammi, A., P. Siikamäki, and K. Mustajärvi. 1999. Genetic diversity, population size, and fitness in central and peripheral populations of a rare plant *Lychnis viscaria*. Conservation Biology 13:1069-1078.

Lande, R. 1998. Anthropogenic, ecological and genetic factors in extinction and conservation. Researches on Population Ecology 40:259–269.

Lesica, P. 1986. Vegetation and flora of Pine Butte Fen, Teton County, Montana. Great Basin Naturalist 46:22-32.

Lesica, P. and F.W. Allendorf. 1992. Are small populations of plants worth preserving? Conservation Biology 6:135-139.

Lesica, P. and F.W. Allendorf. 1995. When are peripheral populations valuable for conservation? Conservation Biology 9:753-760.

Levin, D.A. and H.W. Kerster. 1974. Gene flow in seed plants. Evolutionary Biology 7:139-220.

MacArthur, R.H. and E.O. Wilson. 1967. The Theory of Island Biogeography. Princeton University Press, Princeton, NJ.

Maschinski, J. 2001. Impacts of ungulate herbivores on a rare willow at the southern edge of its range. Biological Conservation 101:119-130.

Matthies, D., I. Bräuer, W. Maibom, and T. Tscharntke. 2004. Population size and the risk of local extinction: empirical evidence from rare plants. Oikos 105:481-488.

McBride, J.R. and J. Strahan. 1984. Establishment and survival of woody riparian species on gravel bars of an intermittent stream. American Midland Naturalist 112:235-245.

McCarty, J.P. 2001. Ecological consequences of recent climate change. Conservation Biology 15:320-331.

Menges, E.S. 1991. The application of minimum viable population theory to plants. Chapter 3 *in* D.A. Falk and K.E. Holsinger, editors. Genetics and Conservation of Rare Plants. Oxford University Press, New York, NY.

Menke, J. editor. 1977. Symposium on livestock interaction with wildlife, fisheries and their environments. Sparks, NV. USDA Forest Service, Pacific Southwest Forest and Range Experimental Station, Berkeley, CA.

Merigliano, M.F. 1998. Cottonwood and willow demography on a young island, Salmon River, Idaho. Wetlands 18: 571-576.

Millar, C.I. and W.J. Libby. 1991. Strategies for conserving clinal, ecotypic, and disjunct population diversity in widespread species. Chapter 10 *in* D.A. Falk and K.E. Holsinger, editors. Genetics and Conservation of Rare Plants. Oxford University Press, New York, NY.

Miller, A. 2005. Personal communication with National Center for Genetic Resource Preservation Seed Analyst regarding *Salix candida*.

Morris, W., D. Doak, M. Groom, P. Kareiva, J Fieberg, L. Gerber, P. Murphy, and D. Thomson. 1999. A Practical Handbook for Population Viability Analysis. The Nature Conservancy.

National Research Council. 2001. Compensating for Wetlands Losses under the Clean Water Act. National Academy Press, Washington, D.C.

NatureServe Explorer: An online encyclopedia of life, version 4.7. NatureServe, Arlington, VA. Available online at: http://www.natureserve.org/explorer/index.htm.

Neid, S.L., K. Decker, and D.G. Anderson. 2004 (Draft). *Salix myrtillifolia* Anderss. (blueberry willow): A Technical Conservation Assessment. Colorado Natural Heritage Program, Colorado State University, Fort Collins, CO.

Newman, E.I. and P. Reddell. 1987. The distribution of mycorrhizas among families of vascular plants. New Phytologist 106:745-751.

Newsholme, C. 1992. Willows: the genus *Salix*. B.T. Batsford Ltd. London. 224 pp.

Nieuwland, J.A. 1914. Notes on our local plants. V. American Midland Naturalist 3:217-243.

Oostermeijer, J.G.B., S.H. Luijten, and J.C.M. den Nijs. 2003. Integrating demographic and genetic approaches in plant conservation. Biological Conservation 113:389-398.

Orians, C.M., M.E. Griffiths, B.M. Roche, and R.S. Fritz. 2000. Phenolic glycosides and condensed tannins in *Salix sericea*, *S. eriocephala* and their F1 hybrids: not all hybrids are created equal. Biochemical Systematics and Ecology 28:619-632.

Ottenbreit, K.A. and R.J. Staniforth. 1992. Life cycle and age structure of ramets in an expanding population of *Salix exigua* (sandbar willow). Canadian Journal of Botany 70:1141-1146.

Owen, D.E. and J.K. Otton. 1995. Mountain wetlands – efficient uranium filters, potential impacts. Ecological Engineering 5:77-93.

Pearson, J.A. and M.J. Leoschke. 1992. Floristic composition and conservation status of fens in Iowa. Iowa Academy of Science 99(2-3):41-52.

Peeters, L. and O. Totland. 1999. Wind to insect pollination ratios and floral traits in five alpine *Salix* species. Canadian Journal of Botany 77:556-563.

Pei, M.H., C. Ruiz, C. Bayon, and T. Hunter. 2004. Rust resistance in *Salix* to *Melampsora larici-epitea*. Plant Pathology 53:770-779.

Peters, R.L. and T.E. Lovejoy, editors. 1992. Global warming and biological diversity. Yale University Press, New Haven, CT.

Pikes Peak Area Council of Governments. 2003. Water Quality Management (208) Plan. Available online at: http://www.ppacg.org/Envir/Water/208%20Plan/208.htm.

Platt, J.R. 1964. Strong inference. Science 146:347-353.

Popovich, S.J. 2006. Personal communication with Botanist, U.S. Forest Service Arapaho-Roosevelt National Forests and Pawnee National Grassland, Fort Collins, CO, regarding Boston Peak fen.

Primak, R.B. 1995. A Primer of Conservation Biology. Sinauer Associates, Inc. Sunderland, MA.

Quilambo, O.A. 2003. The vesicular-arbuscular mycorrhizal symbiosis. African Journal of Biotechnology 2:539-546.

Raven, J.A. 1992. The physiology of *Salix*. Proc. Royal Soc. Edinburgh 98B:49-62.

Raven, P.H., R.F. Evert, and S.E. Eichhorn. 1986. Biology of Plants, Fourth edition. Worth Publishers, Inc., New York, NY.

Rohwer, J. and K. Kubitzki. 1984. *Salix martiana*, a regularly hermaphrodite willow. Plant Systematics and Evolution 144:99-101.

Rowlee, W.W. and K.M. Wiegand. 1896. *Salix candida* Willd. and its hybrids. Bulletin of the Torrey Botanical Club 23:194-201.

Sacchi, C.F. and P.W. Price. 1988. Pollination of the arroyo willow, *Salix lasiolepis*: role of insects and wind. American Journal of Botany 75:1387-1393.

Sacchi, C.F. and P.W. Price. 1992. The relative roles of abiotic and biotic factors in seedling demography of arroyo willow (*Salix lasiolepis*: Salicaceae). American Journal of Botany 79:395-405.

Sanderson, J. 2000. Memo: Assessment of potential effects of Aurora's Conjunctive Use Project on *Ptilagrostis porteri* (Rydberg) W.A. Weber.

Sanderson, J. 2006. Personal communication with Ecologist/Hydrologist, Fort Collins, Colorado, regarding *Salix candida* and South Park fens.

Sanderson, J. and M. March. 1996. Extreme rich fens of South Park, Colorado: their distribution, identification, and natural heritage significance. Colorado Natural Heritage Program, Colorado State University, Fort Collins, CO. Available online at: http://www.cnhp.colostate.edu/documents/1996/Extreme_Rich_Fens_of_South_Park_Colorado.pdf.

Sanderson, J., A. Carpenter, and T. Schuz. In prep. What is peatland "restoration"? Lessons from a Colorado fen.

Schulz, T.T. and W.C. Leininger. 1990. Differences in riparian vegetation structure between grazed areas and exclosures. Journal of Range Management 43:295-299.

Shaffer, M.L. 1981. Minimum population sizes for species conservation. BioScience 31:131-134.

Sipura, M. 2002. Contrasting effects of ants on the herbivory and growth of two willow species. Ecology 83:2680-2690.

Smith, E.C. 1942. The willows of Colorado. American Midland Naturalist 27:217-252.

Smith, J.A., R.A. Blanchetete, and G. Newcombe. 2004. Molecular and morphological characterization of the willow rust fungus, *Melampsora epitea*, from arctic and temperate hosts in North America. Mycologia 96:1330-1338.

South Dakota Natural Heritage Program. 2004. Element occurrence records for *Salix candida*. Pierre, SD.

Spackman, S., D. Culver, and J. Sanderson. 2001. Park County Inventory of Critical Biological Resources. Colorado Natural Heritage Program, Colorado State University, Fort Collins, CO.

Spackman, S., B. Jennings, J. Coles, C. Dawson, M. Minton, A. Kratz, and C. Spurrier. 1997. Colorado rare plant field guide. Prepared for the Bureau of Land Management, the U.S. Forest Service and the U.S. Fish and Wildlife Service by the Colorado Natural Heritage Program. Available online at: http://www.cnhp.colostate.edu/rareplants/intro.html.

Stammel, B. and K. Kiehl. 2004. Do hoof prints actually serve as a regeneration niche for plant species in fens? Phytocoenologia 34:271-286.

Stein, S.J., P.W. Price, W.G Abrahamson, and C.F. Sacchi. 1992. The effect of fire on stimulating willow regrowth and subsequent attack by grasshoppers and elk. Oikos 65:190-196.

Thomson, J.D. and S.C.H. Barrett. 1981. Selection for outcrossing, sexual selection, and the evolution of dioecy in plants. American Naturalist 118:443-449.

Thomson, J.D. and J. Brunet. 1990. Hypotheses for the evolution of dioecy in seed plants. Trends in Ecology and Evolution 5:11-16.

Thormann, M.N., R.S. Currah, and S.E. Bayley. 1999. The mycorrhizal status of the dominant vegetation along a peatland gradient in southern boreal Alberta, Canada. Wetlands 19:438-450.

Totland, O. and M. Sottocornola. 2001. Pollen limitation of reproductive success in two sympatric alpine willows (Salicaceae) with contrasting pollination strategies. American Journal of Botany 88:1011-1015.

USDA Natural Resources Conservation Service. The PLANTS Database Web Page. [Accessed 2005]. Located at; National Plant Data Center, Baton Rouge, LA . http://plants.usda.gov/plants/index.html.

U.S. Fish and Wildlife Service. 1998. Memorandum dated June 8, 1998 from Regional Director, Region 6 U.S. Fish and Wildlife Service to Project Leaders for Ecological Services, Refuges and Wildlife, and Fish and Wildlife Management Assistance. Region 6. Subject: Regional Policy on the Protection of Fens.

U.S. Fish and Wildlife Service. 2000. Guidelines for conducting and reporting botanical inventories for federally listed, proposed, and candidate plants. Available online at: http://ventura.fws.gov/es/protocols/botanicalsurvey_protocol.pdf.

U.S. Fish and Wildlife Service. 2002. Waubay National Wildlife Refuge Complex Comprehensive Conservation Plan. U.S. Fish and Wildlife Service, Waubay, SD.

USDA Forest Service, Medicine Bow National Forest. 2003. Revised Land and Resource Management Plan Final Environmental Impact Statement, Appendix I, Part 2: Biological Evaluation of Sensitive Species. Available online at: http://www.fs.fed.us/r2/mbr/projects/forestplans/mb/eis_apps/final_eis_app_i_babe.pdf.

USDA Forest Service, Pike and San Isabel National Forests. No date. Supplemental Wild and Scenic River Study Report and Draft Legislative Environmental Impact Statement. Available online at: http://www.fs.usda.gov/r2/psicc/publications/environmental_impact_statements/eis_wild_and_scenic/index.html.

USDA Forest Service, Rocky Mountain Region. 2002. Memorandum dated March 19, 2002 from Director, Renewable Resources, USDA Forest Service, Rocky Mountain Region to Forest Supervisors. Subject: Wetland Protection – Fens.

USDA Forest Service, Rocky Mountain Region. 2003. Threatened, Endangered, and Sensitive Plants and Animals. Chapter 2670 *in* USDA Forest Service, ed. Forest Service Manual Rocky Mountain Region. USDA Forest Service Region 2, Lakewood, CO.

USDA Forest Service, Rocky Mountain Region. 2005. Region 2 Regional Forester's Sensitive Species List. Available online at: http://www.fs.fed.us/r2/projects/scp/sensitivespecies/index.shtml.

USDI Bureau of Land Management. 2000. Colorado BLM State Director's Sensitive Species List (Animals and Plants). Available online at: http://www.co.blm.gov/botany/sens_species.htm.

USDI Bureau of Mines. 1994. Minerals Yearbook; Metals and Minerals. U.S. Government Printing Office, Washington, D.C.

Walker, B.H. 1991. Ecological consequences of atmospheric and climate change. Climatic Change 18:301-316.

Walther, G., E. Post, P. Convey, A. Menzel, C. Parmesank, T.J.C. Beebee, J. Fromentin, O. Hoegh-Guldberg, and F. Bairlein. 2002. Ecological responses to recent climate change. Nature 416:389-395.

Weber, W.A. 2003. The middle Asian element in the Southern Rocky Mountain flora of the western United States: a critical biogeographical review. Journal of Biogeography 30:649-685.

Weber, W.A. and R.C. Wittmann. 2001. *Colorado Flora: Eastern Slope*. University Press of Colorado, Niwot, CO.

Welsh, S.L. 1974. *Anderson's Flora of Alaska and Adjacent Parts of Canada*. Brigham Young University Press, Provo, UT. 724 pp.

Windell, J.T., B.E. Willard, D.J. Cooper, C.F. Knud-Hansen, L.P. Rink, and G.N. Kiladis. 1986. An ecological characterization of rocky mountain montane and subalpine wetlands. National Ecology Center, U.S. Department of the Interior, Washington, D.C.

Woods, S.W. 2000. Hydrologic effects of the Grand Ditch on streams and wetlands in Rocky Mountain National Park, Colorado. M.S. Thesis, Colorado State University, Fort Collins, CO.

Wyoming Natural Diversity Database. 2006. Element occurrence records for *Salix candida*. Laramie, WY.

Yampolsky, C. and H. Yampolsky. 1922. Distribution of sex forms in the phanerogamic flora. Bibl. Genet. (Lpz.) 3: 1-62.

Young, J.A. and C.D. Clements. 2003. Seed germination of willow species from a desert riparian ecosystem. Journal of Range Management 56:496-500.